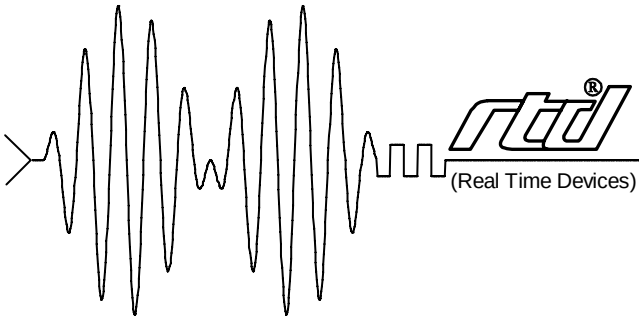
DM300/DM5300 User's Manual



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"Accessing the Analog World"®

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ISO9001 and AS9100 Certified

DM300/DM5300
User's Manual

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TABLE OF CONTENTS

INTRODUCTION ***i*-1**

Analog-to-Digital Conversion *i*-3
Digital-to-Analog Conversion *i*-4
Digital I/O *i*-4
What Comes With Your Board *i*-4
Board Accessories *i*-4
Hardware Accessories *i*-4
Using This Manual *i*-4
When You Need Help *i*-5

CHAPTER 1 — MODULE SETTINGS **1-1**

Factory-Configured Switch and Jumper Settings 1-3
P3 — User Timer/Counter Output Select (Factory Setting: P2-43: TRIG, P2-44: OT0) 1-4
P4 — User Timer/Counter Clock Source (Factory Settings: CLK0-OSC, CLK1-OT0, CLK2-OT1) 1-4
P5 — User Timer/Counter Gate Source (Factory Settings: All Gates: +5V) 1-5
P6 — Single-Ended/Differential Analog Inputs (Factory Setting: S (16 Single-Ended)) 1-6
P7 — Analog Input Voltage Range and Polarity (Factory Setting: 5V, BI (±2.5 Volts)) 1-6
P8 — DAC 1 Output Voltage Range (Factory Setting: +5 to -5 volts) 1-6
P9 — DAC 2 Output Voltage Range (Factory Setting: +5 to -5 volts) 1-7
S1 — Base Address (Factory Setting: 300 hex (768 decimal)) 1-8
Pull-up/Pull-down Resistors on Digital I/O Lines 1-9
J4 — Trigger Input Select (Factory Setting: TR) 1-10
Gm, Gain Multiplier Circuitry 1-10

CHAPTER 2 — MODULE INSTALLATION **2-1**

Module Installation 2-3
External I/O Connections 2-3
Connecting the Analog Input Pins 2-4
Connecting the Trigger In and Trigger Out Pins, Cascading Boards 2-5
Connecting the Analog Outputs 2-6
Connecting the Timer/Counters and Digital I/O 2-6
Running the 5300DIAG Diagnostics Program 2-6

CHAPTER 3 — HARDWARE DESCRIPTION **3-1**

A/D Conversion Circuitry 3-3
Analog Inputs 3-3
V/F Converter 3-4
Timing and Counting Circuits 3-5
D/A Converter 3-5
Timer/Counters 3-5
Digital I/O, Programmable Peripheral Interface 3-6
Interrupts 3-7

CHAPTER 4 — MODULE OPERATION AND PROGRAMMING 4-1

Defining the I/O Map 4-3
BA + 0: A/D Data Low Byte (Read Only) 4-4
BA + 1: A/D Data Middle Byte (Read Only) 4-4
BA + 2: A/D Data High Byte (Read Only) 4-4
BA + 3: Board Ready/Clear 20-bit Conversion Counter (Read/Write) 4-4
BA + 4: 8254 Timer/Counter 0 (Read/Write) 4-4
BA + 5: 8254 Timer/Counter 1 (Read/Write) 4-5
BA + 6: 8254 Timer/Counter 2 (Read/Write) 4-5
BA + 7: 8254 Control Word (Write Only) 4-5
BA + 8: PPI Port A — Digital I/O (Read/Write) 4-5
BA + 9: PPI Port B — Channel/Gain Select (Read/Write) 4-5
BA + 10: PPI Port C — Digital I/O (Read/Write) 4-6
BA + 11: 8255 PPI Control Word (Write Only) 4-6
BA + 12: D/A Converter 1 LSB (Read/Write) 4-8
BA + 13: D/A Converter 1 MSB (Read/Write) 4-8
BA + 14: D/A Converter 2 LSB (Read/Write) 4-8
BA + 15: D/A Converter 2 MSB (Read/Write) 4-8
BA + 16: User 8254 Timer/Counter 0 (Read/Write) 4-8
BA + 17: User 8254 Timer/Counter 1 (Read/Write) 4-8
BA + 18: User 8254 Timer/Counter 2 (Read/Write) 4-9
BA + 19: User 8254 Control Word (Write Only) 4-9
BA + 20: Board Setup Register (Write Only) 4-9
BA + 21: A/D Trigger Mode Register (Write Only) 4-10
BA + 22: Reset/Update DACs (Read/Write) 4-10
A/D Conversions 4-11
Programming the 8254 Timer 4-11
Initializing the 8255 PPI 4-12
Clearing the Board 4-13
Setting the Channel 4-13
Setting the Gain 4-13
Conversion Modes 4-14
Single Convert Mode 4-14
Continuous Convert Mode 4-16
Cascading Boards 4-18
Reading the Converted Data 4-19
D/A Conversions 4-19
User-Available 8254 Timer/Counter 4-21
Digital I/O 4-22
Interrupts 4-22
Example Programs 4-23
C and Pascal Programs 4-23
BASIC Programs 4-23

CHAPTER 5 — CALCULATING FREQUENCIES, VOLTAGES, AND BITS 5-1

Calculating the Settings for the 8254 Timer 5-3
Binary Calculations 5-3
Decimal Calculations 5-5
Conversion Results and Correction Factor 5-7
Input Voltages and Output Frequencies 5-8
Input Voltage Calculations 5-9
Bit Calculations 5-9

CHAPTER 6 — CALIBRATION 6-1

Required Equipment 6-3
V/F Calibration 6-3
D/A Calibration 6-4

APPENDIX A — DM5300 SPECIFICATIONS A-1

APPENDIX B — P2 CONNECTOR PIN ASSIGNMENTS B-1

APPENDIX C — COMPONENT DATA SHEETS C-1

APPENDIX D — WARRANTY D-1

LIST OF ILLUSTRATIONS

1-1 Module Layout Showing Factory-Configured Settings 1-3
1-2 User Timer/Counter Output Select Jumpers, P3 1-4
1-3 User Timer/Counter Clock Source Jumpers, P4 1-4
1-4 8254 Timer/Counter Circuit Block Diagram 1-5
1-5 User Timer/Counter Gate Source Jumpers, P5 1-5
1-6 Single-Ended/Differential Analog Input Signal Type Jumpers, P6 1-6
1-7 Analog Input Voltage Range and Polarity, P7 1-6
1-8 DAC 1 Output Voltage Range Jumper, P8 1-7
1-9 DAC 2 Output Voltage Range Jumper, P9 1-7
1-10 Base Address Switch, S1 1-8
1-11 Adding Pull-ups and Pull-downs to Digital I/O Lines 1-10
1-12 J4, Trigger Input Select 1-10
1-13 Gain Circuitry and Formula for Calculating Gm 1-11
1-14 Diagram for Removal of Solder Short 1-11
2-1 P2 I/O Connector Pin Assignments 2-4
2-2 Single-Ended Input Connections 2-4
2-3 Differential Input Connections 2-5
2-4 Cascading Two Boards for Simultaneous Sampling 2-6
3-1 DM5300 Block Diagram 3-3
3-2 V/F Timing and Counting Block Diagram 3-4
3-3 User 8254 Timer/Counter Circuitry 3-6
4-1 Single Convert Mode Timing Diagram 4-14
4-2 Single Convert Mode Flow Diagram 4-15
4-3 Continuous Convert Mode Timing Diagram 4-16
4-4 Continuous Convert Mode Flow Diagram 4-17
4-5 Cascaded Boards, Single Convert Mode Flow Diagram 4-18
4-6 User 8254 Timer/Counter Circuitry 4-21
6-1 Module Layout 6-3

INTRODUCTION

The DM5300 variable resolution integrating analog dataModule turns your IBM PC/XT/AT compatible cpuModule or other PC/104 computer into a high-performance data acquisition and control system. Ultra-compact for embedded and portable applications, the DM5300 features:

- 8 differential or 16 single-ended analog input channels,
- Resolution to 18 bits using a synchronous voltage-to-frequency converter,
- 0 to +5, 0 to +10, ±2.5, or ±5 volt input range,
- Programmable gains of 1, 2, 4, and 8 with an on-board gain multiplier circuit,
- Clock controlled A/D conversion,
- Software selectable system clock interrupt source and interrupt channel,
- Trigger in and trigger out for external triggering or cascading boards,
- Two 12-bit analog output channels,
- ±5, ±10, 0 to +5, or 0 to +10 volt analog output range,
- Three user available 16-bit timer/counters,
- 16 8255-based TTL/CMOS compatible digital I/O lines,
- +5 volt operation (DM5300).

The following paragraphs briefly describe the major functions of the module. More detailed discussions of module functions are included in Chapter 3, *Hardware Description*, and Chapter 4, *Module Operation and Programming*. The module setup is described in Chapter 1, *Module Settings*.

The difference between the DM300 and the DM5300 modules is in the power supply requirements. The DM300 module needs a +5, +12, and -12 volt supply for proper operation. The DM5300 module needs only a +5 volt power supply, making it ideal for portable applications.

Analog-to-Digital Conversion

The analog-to-digital (A/D) conversion circuitry receives up to eight differential or 16 single-ended analog inputs and converts these inputs into frequencies. The frequencies are represented by 20-bit plus overflow words (in 3 x 8-bit format) which are read and/or transferred to PC memory.

An on-board header connector lets you jumper the inputs for differential or single-ended operation. Two unipolar and two bipolar ranges can be selected: 0 to +5, 0 to +10, ±2.5, or ±5 volts. The module is calibrated at the factory for ±2.5 volts. Software programmable gains of 1, 2, 4, and 8 with an on-board gain multiplier circuitry let you customize the input range. Over voltage protection to ±35 volts is provided at the inputs.

A/D conversions are performed by a voltage-to-frequency (V/F) converter. This exceptionally accurate converter technology lets you vary the resolution of your conversion while maintaining the full input voltage range. For example, with a 1 MHz system clock and the input range set for 5 volts, 10-bit conversions are performed at a rate of 488 samples per seconds with a resolution of 4.88 millivolts, 12-bit conversions are performed at a rate of 122 samples per second with a resolution of 1.22 millivolts, and 18-bit conversions are performed at a rate of 2 samples per second with a resolution of 19 microvolts.

The converted data is read and/or transferred to PC memory, one byte at a time, through the PC data bus.

Digital-to-Analog Conversion

The digital-to-analog (D/A) circuitry features two independent 12-bit analog output channels with individually jumper-selectable output ranges of -5 to +5 volts, -10 to +10 volts, 0 to +5 volts, or 0 to +10 volts. Data is programmed into the D/A converter by writing two 8-bit words, the LSB and the MSB. Both outputs can be simultaneously updated by writing to an I/O port.

Digital I/O

The DM5300 has 16 TTL/CMOS compatible digital I/O lines which can be directly interfaced with external devices or signals to sense switch closures, trigger digital events, or activate solid-state relays. These lines are provided by the 8255 programmable peripheral interface (PPI). Pads for activating pull-up/pull-down resistors are included on the module. Installation procedures are given near the end of Chapter 1, *Module Settings*.

What Comes With Your Module

You receive the following items in your DM5300 package:

- DM5300 analog I/O dataModule
- Mounting hardware
- Software and diagnostics diskette with example programs in BASIC and C
- User's manual

If any item is missing or damaged, please call RTD Embedded Technologies Inc. Customer Service Department at (814) 234-8087. If you require service outside the U.S., contact your local distributor.

Module Accessories

In addition to the items included in your DM5300 package, RTD Embedded Technologies Inc. offers a full line of software and hardware accessories. Call your local distributor or our main office for more information about these accessories and for help in choosing the best items to support your module's application.

Hardware Accessories

Hardware accessories for the DM5300 include the TMX32 analog input expansion board with thermocouple compensation which can expand a single input channel on your board to 16 differential or 32 single-ended input channels, MR series mechanical relay output boards, OP series optoisolated digital input boards, the OR16 mechanical relay/optoisolated digital I/O board, the USF4 universal sensor front-end with sensor excitation, the TB50 terminal board and XB50 prototype/terminal board for prototype development and easy signal access, the DM14 extender board for simplified testing and debugging of prototype circuitry, and the XT50 twisted pair ribbon cable assembly for external interfacing.

Using This Manual

This manual is intended to help you install your new module and get it running quickly, while also providing enough detail about the module and its functions so that you can enjoy maximum use of

its features even in the most complex applications. We assume that you already have an understanding of data acquisition principles and that you can customize the example software or write your own applications programs.

When You Need Help

This manual and the example programs in the software package included with your module provide enough information to properly use all of the module's features. If you have any problems installing or using this module, contact our Technical Support Department, (814) 234-8087, during regular business hours, eastern standard time or eastern daylight time, or send a FAX requesting assistance to (814) 234-5218. When sending a FAX request, please include your company's name and address, your name, your telephone number, and a brief description of the problem.

CHAPTER 1 MODULE SETTINGS

The DM5300 has jumper and switch settings you can change if necessary for your application. The module is factory-configured as listed in the table and shown on a diagram in the beginning of this chapter. Should you need to change these settings, use these easy-to-follow instructions before you install the module in your system.

Note that by installing jumpers in the associated pads, you can configure the 16 available digital I/O lines to be pulled up or pulled down. This procedure is explained near the end of this chapter.

Also note that by installing resistive components, you can add your own gain multiplier for the software programmable binary gains of 1, 2, 4, and 8. The gain multiplier circuitry is described at the end of this chapter.

Factory-Configured Switch and Jumper Settings

Table 1-1 lists the factory settings of the user-configurable switch and jumpers on the DM5300. Figure 1-1 shows the module layout and the locations of the factory-set jumpers. The following paragraphs explain how to change the factory settings.

Table 1-1 Factory Settings		
Switch/Jump	Function Controlled	Factory Settings
P3	Sets the user timer/counter output signals available at P2-43 and P2-44	P2-43: TRIG, P2-44: OUT0
P4	Sets the clock sources for the user timer/counters	CLK0:OSC, CLK1:OT0, CLK2:OT1 (cascaded)
P5	Sets the gate sources for the user timer/counters	GATE0:+5V, GATE1:+5V, GATE2:+5V
P6	Sets the analog input as 16 single-ended or 8 differential	16 single-ended (3 jumpers installed on S pins)
P7	Sets the analog input voltage range and polarity	5V, BI (-2.5 to +2.5 volts)
P8	Sets the D/A output voltage range for DAC 1	+-5, X1 (-5 to +5 volts)
P9	Sets the D/A output voltage range for DAC 2	+-5, X1 (-5 to +5 volts)
S1	Sets the base address	300 hex (768 decimal)
J4	Connects TRIGGER IN (P2-39) or TIMER/COUNTER 2 out 2 to EPLD trigger input	TRIGGER IN (P2-39)

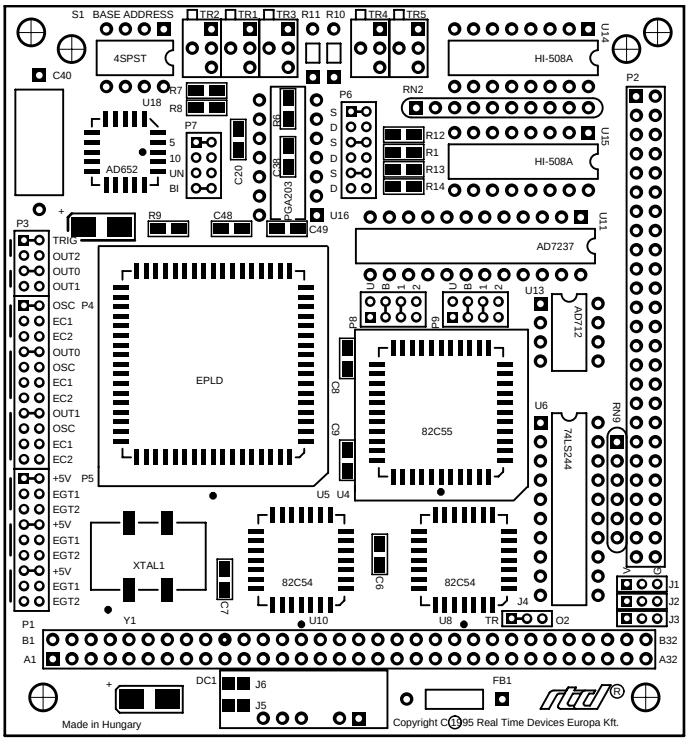


Fig. 1-1 — Module Layout Showing Factory-Configured Settings

P3 -User Timer/Counter Output Select (Factory Setting: P2-43: TRIG, P2-44: OUT0)

This header connector, shown in Figure 1-2, lets you select one of two signals to be present at each of two of the P2 I/O connector pins, P2-43 and P2-44. This allows you more flexibility when setting up the module. P2-43 can be configured to provide an external trigger (TRIG) or the output of user timer/counter 2 (OUT2). P2-44 can be configured to provide the output of user timer/counter 0 (OUT0) or the output of user timer/counter 1 (OUT1). Note that when you cascade multiple modules, you must configure P2-43 to carry the external trigger signal (TRIG) on each module that outputs a trigger to the next module in the chain.

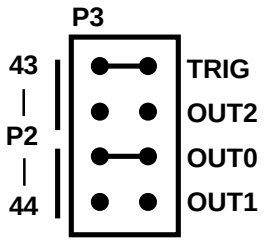


Fig. 1-2 — User Timer/Counter Output Select Jumpers, P3

P4 - User Timer/Counter Clock Source (Factory Settings: CLK0-OSC, CLK1-OUT0, CLK2-OUT1)

This header connector, shown in Figure 1-3, lets you select the clock sources for the user available 8254 timer/counters, TC0, TC1, and TC2. The factory setting cascades all three timer/counters, with the clock source for TC0 being the on-board 2 MHz oscillator, the output of TC0 providing the clock for TC1, and the output of TC1 providing the clock for TC2. You can connect any or all of the sources to either of two external clock inputs (the first source labeled EC1 on the header is EXT CLK1 at P2-41, and the second source labeled EC2 on the header is EXT CLK2 at P2-45), or you can set TC1 and TC2 to be clocked by the 2 MHz oscillator. Figure 1-4 shows a block diagram of the timer/counter circuitry to help you with these connections.

NOTE: When installing jumpers on this header, make sure that only one jumper is installed in

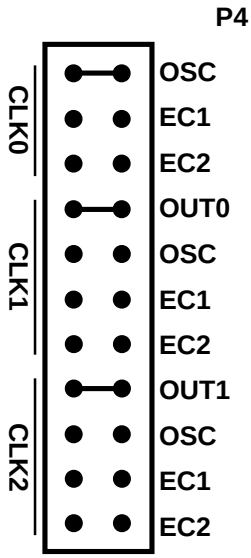


Fig. 1-3 — User Timer/Counter Clock Source Jumpers, P4

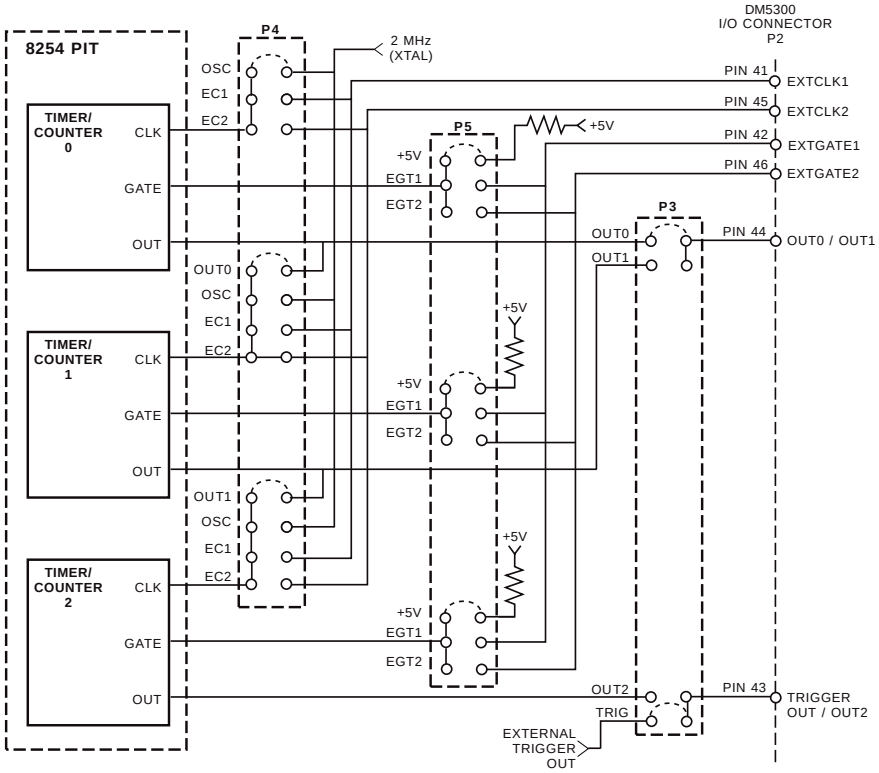


Fig. 1-4 — 8254 Timer/Counter Circuit Block Diagram

each group of CLK pins.

P5 — User Timer/Counter Gate Source (Factory Settings: All Gates: +5V)

This header connector, shown in Figure 1-5, lets you select the gate sources for the user available 8254 timer/counters, TC0, TC1, and TC2. The factory setting ties all three gates high, to an on-board +5 volt source. You can connect any or all of the gates to either of two external gate inputs (the first source labeled EGT1 on the header is EXT GATE1 at P2-42, and the second source labeled EGT2 on the header is EXT GATE2 at P2-46). Figure 1-4 shows a block diagram of the

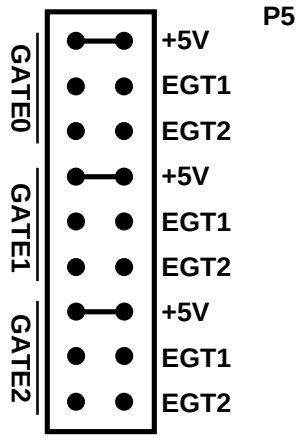


Fig. 1-5 — User Timer/Counter Gate Source Jumpers, P5

timer/counter circuitry to help you with these connections.

NOTE: When installing jumpers on this header, make sure that only one jumper is installed in each group of GATE pins.

P6 — Single-Ended/Differential Analog Inputs (Factory Setting: S (16 Single-Ended))

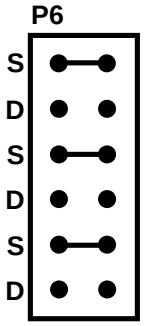


Fig. 1-6 — Single-Ended/Differential Analog Input Signal Type Jumpers, P6

This header connector, shown in Figure 1-6, is used to configure the DM5300 for 8 differential or 16 single-ended analog input channels. When operating in the 16 input single-ended mode, three jumpers must be installed across the S pins. When operating in the 8 input differential mode, three jumpers must be installed across the D pins. DO NOT install jumpers across both S and D pins at the same time!

P7 — Analog Input Voltage Range and Polarity (Factory Setting: 5V, BI (±2.5 Volts)

P7, shown in Figure 1-7, sets the analog input voltage range and polarity. The module can be set up

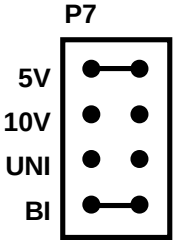


Fig. 1-7 — Analog Input Voltage Range and Polarity, P7

to operate over a range of 5 or 10 volts, unipolar or bipolar. The module's four possible ranges are 0 to +5, 0 to +10, ±2.5, and ±5 volts. Figure 1-7 shows the factory setting of -2.5 to +2.5 volts.

NOTE: If you change the analog input range and/or polarity, you should recalibrate the board according to the instructions in Chapter 6, *Calibration*. Otherwise, you may get erroneous data.

P8 — DAC 1 Output Voltage Range (Factory Setting: +5 to -5 volts)

Voltage Range	Jumpers (Top to Bottom)			
	U	B	X1	X2
-5 to +5 volts	OFF	ON	ON	OFF
0 to +5 volts	ON	OFF	ON	OFF
-10 to +10 volts	OFF	ON	OFF	ON
0 to +10 volts	ON	OFF	OFF	ON

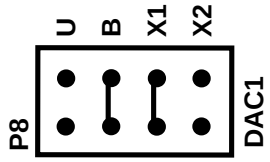


Fig. 1-8 — DAC 1 Output Voltage Range Jumper, P8

This header connector, shown in Figure 1-8, sets the output voltage range for DAC 1 at 0 to +5, ±5, 0 to +10, or ±10 volts. Two jumpers must be installed, one to select the range and one to select the multiplier. The first two positions select the range, bipolar (±5) or unipolar (5). The next two positions select the multiplier, X2 or X1. When a jumper is on the X2 multiplier pins, the range values become ±10 and 10. The table on the next page shows the four possible combinations of jumper settings. This header does not have to be set the same as P9.

Voltage Range	Jumpers (Top to Bottom)			
	U	B	X1	X2
-5 to +5 volts	OFF	ON	ON	OFF
0 to +5 volts	ON	OFF	ON	OFF
-10 to +10 volts	OFF	ON	OFF	ON
0 to +10 volts	ON	OFF	OFF	ON

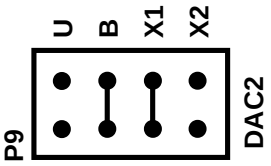


Fig. 1-9 — DAC 2 Output Voltage Range Jumper, P9

P9 — DAC 2 Output Voltage Range (Factory Setting: +5 to -5 volts)

This header connector, shown in Figure 1-9, sets the output voltage range for DAC 2 at 0 to +5, ±5, 0 to +10, or ±10 volts. Two jumpers must be installed, one to select the range and one to select the multiplier. The first two positions select the range, bipolar (±5) or unipolar (5). The next two positions select the multiplier, X2 or X1. When a jumper is on the X2 multiplier pins, the range values become ±10 and 10. The table below shows the four possible combinations of jumper settings. This header does not have to be set the same as P8.

S1 — Base Address (Factory Setting: 300 hex (768 decimal))

One of the most common causes of failure when you are first trying your module is address contention. Some of your computer's I/O space is already occupied by internal I/O and other peripherals. When the DM5300 attempts to use I/O address locations already used by another device, contention results and the module does not work.

Table 1-2 Base Address Switch Settings, S1

Base Address Decimal / (Hex)	Switch Setting 4 3 2 1	Base Address Decimal / (Hex)	Switch Setting 4 3 2 1
512 / (200)	0 0 0 0	768 / (300)	1 0 0 0
544 / (220)	0 0 0 1	800 / (320)	1 0 0 1
576 / (240)	0 0 1 0	832 / (340)	1 0 1 0
608 / (260)	0 0 1 1	864 / (360)	1 0 1 1
640 / (280)	0 1 0 0	896 / (380)	1 1 0 0
672 / (2A0)	0 1 0 1	928 / (3A0)	1 1 0 1
704 / (2C0)	0 1 1 0	960 / (3C0)	1 1 1 0
736 / (2E0)	0 1 1 1	992 / (3E0)	1 1 1 1
0 = Closed, 1 = Open			

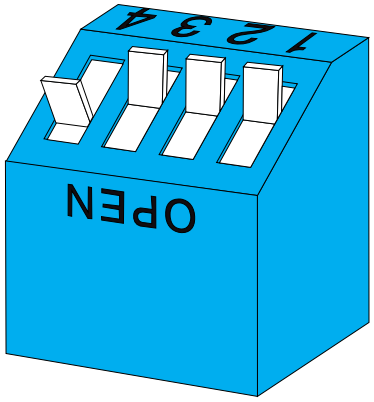


Fig. 1-10 — Base Address Switch, S1

To avoid this problem, the DM5300 has an easily accessible four-position DIP switch, S1, which lets you select any one of 16 starting addresses in the computer's I/O. Should the factory setting of 300 hex (768 decimal) be unsuitable for your system, you can select a different base address simply by setting the switches to any one of the values listed in Table 1-2. The table shows the switch settings and their corresponding decimal and hexadecimal (in parentheses) values. Make sure that you verify the order of the switch numbers on the switch (1 through 4) before setting them. When the switches are pulled forward, they are OPEN, or set to logic 1, as labeled on the DIP switch package. When you set the base address for your module, record the value in the table inside the back cover. Figure 1-10 shows the DIP switch set for a base address of 300 hex (768 decimal).

Pull-up/Pull-down Resistors on Digital I/O Lines

The 8255 programmable peripheral interface provides 16 TTL/CMOS compatible digital I/O lines which can be interfaced with external devices. These lines are divided into three groups: eight Port A lines, four Port C Lower lines, and four Port C Upper lines. (The eight lines of Port B are used for internal board functions.) You can connect pull-up or pull-down resistors for any or all of these three groups of lines. You may want to pull lines up for connection to switches. This will pull the line high when the switch is disconnected. Or, you may want to pull lines down for connection to relays which control turning motors on and off. These motors turn on when the digital lines controlling them are high. The Port A lines of the 8255 automatically power up as inputs, which can float high during the few moments before the board is first initialized. This can cause the external devices connected to these lines to operate erratically. By pulling these lines down, when the data acquisition system is first turned on, the motors will not switch on before the 8255 is

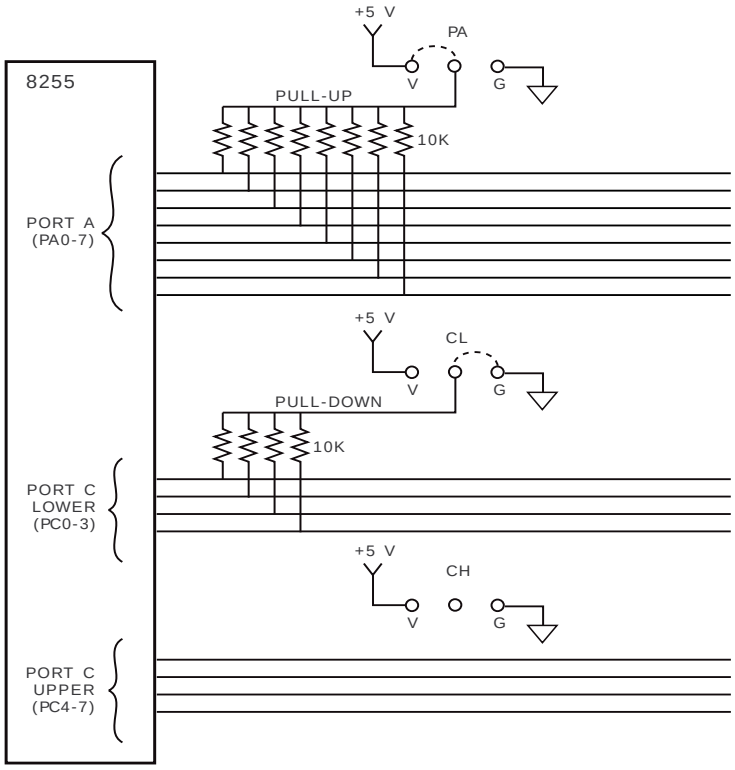


Fig. 1-11 — Adding Pull-ups and Pull-downs to Digital I/O Lines

initialized.

To use the pull-up/pull-down feature, you must connect them into the circuit as pull-ups or pull-downs. Locate the three-hole pads (J1, J2, J3) on the board below the P2 connector. They are labeled G (for ground) on one end and V (for +5V) on the other end. The middle hole is common. J1 is for Port A, J2 is for Port C Lower, and J3 is for Port C Upper. To operate as pull-ups, solder a jumper wire between the common pin (middle pin of the three) and the V pin. For pull-downs, solder a jumper wire between the common pin (middle pin) and the G pin. Figure 1-11 shows Port A lines with pull-ups, Port C Lower with pull-downs, and Port C Upper with no resistors.

J4 — Trigger Input Select (Factory Setting: TR)

This header connector, shown in Figure 1-12, is used to select the input for the triggering circuit.

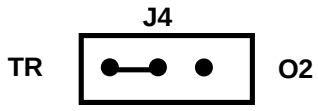


Fig. 1-12 — J4, Trigger Input Select

The two options are TR (TRIGGER IN P2-39) or O2 (user TIMER/COUNTER OUT2). This jumper is used in conjunction with the trigger and interrupt mode set in the register at BA +21. For example, if you would like to use an external signal to trigger the conversion, you would connect your trigger signal to P2-39, set jumper J4 for TR, and program the trigger select at BA +21 (bit D0) for External Trigger.

If you would like to use this timer/counter to trigger the conversions, you would set J4 for O2 and program the trigger select for External Trigger. If you would like to use internal triggering but use the timer to generate interrupts, you would set J4 for O2 and program the trigger register to internal triggering and the IRQ select to External Trigger.

Gm, Gain Multiplier Circuitry

The DM5300 has software programmable binary gains of 1, 2, 4, and 8. A gain multiplier circuit, Gm, is provided so that you can easily configure special gain settings for a specific application. Note that when you use this feature and set up the module for a gain of other than 1, all of the input channels will operate only at your custom gain settings. In other words, if you install circuitry which gives you a gain multiplier of 10, then the four programmable gains available are 10, 20, 40, and 80.

Gm is derived by adding resistors R10 and R11 and trimpot TR3, all located in the upper center area of the module. The resistors and trimpot combine to set the gain, as shown in the diagram and formula in Figure 1-13.

As shown in Figure 1-13, a solder short labeled J7 must be removed from the module to activate the Gm circuitry. This short is located on the **bottom side** of the board under R10 and R11. Figure 1-14 shows the location of the solder short.

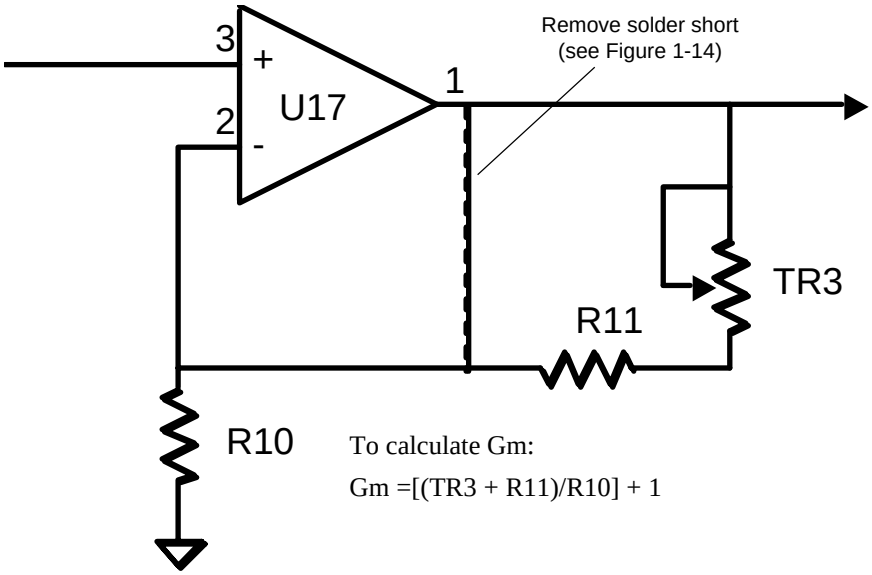


Fig. 1-13 — Gain Circuitry and Formula for Calculating Gm

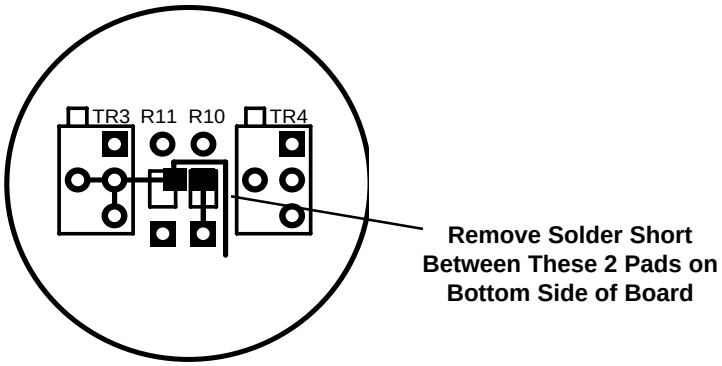


Fig. 1-14 — Diagram for Removal of Solder Short

CHAPTER 2 MODULE INSTALLATION

The DM5300 board is easy to install on your cpuModule or other PC/104 system. This chapter tells you step-by-step how to install and connect the module.

After you have installed the module and made all of your connections, you can turn your system on and run the 5300DIAG diagnostics program included on your example software disk to verify that your module is working.

Module Installation

Keep the module in its antistatic bag until you are ready to install it in your cpuModule™ or other PC/104 based system. When removing it from the bag, hold the module at the edges and do not touch the components or connectors.

Before installing the module in your system, check the jumper settings. Chapter 1 reviews the factory settings and how to change them. If you need to change any settings, refer to the appropriate instructions in Chapter 1. Note that incompatible jumper settings can result in unpredictable module operation and erratic response.

The DM5300 comes with a stackthrough P1 connector. The stackthrough connector lets you stack another module on top of your DM5300.

To install the module, follow the procedures described in the computer manual and the steps below:

1. Turn OFF the power to your system.
2. Touch a metal rack to discharge any static buildup and then remove the module from its antistatic bag.
3. Select the appropriate standoffs for your application to secure the module when you install it in your system (two sizes are included with the module).
4. Holding the module by its edges, orient it so that the P1 bus connector's pin 1 lines up with pin 1 of the expansion connector onto which you are installing the module.
5. After carefully positioning the module so that the pins are lined up and resting on the expansion connector, gently and evenly press down on the module until it is secured on the connector.

   NOTE: Do not force the module onto the connector. If the module does not readily press into place, remove it and try again. Wiggling the module or exerting too much pressure can result in damage to the DM5300 or to the mating module.
6. After the module is installed, connect the cable to I/O connector P2 on the module. When making this connection, note that there is no keying to guide you in orientation. You must make sure that pin 1 of the cable is connected to pin 1 of P2 (pin 1 is marked on the module with a small square). For twisted pair cables, pin 1 is the dark brown wire; for standard single wire cables, pin 1 is the red wire.
7. Make sure all connections are secure.

External I/O Connections

Figure 2-1 shows the DM5300's P2 I/O connector pinout. Refer to this diagram as you make your I/O connections. Note that the +12 and -12 volt signals are available at pins 47 and 49 only if your system power supply provides these voltages.

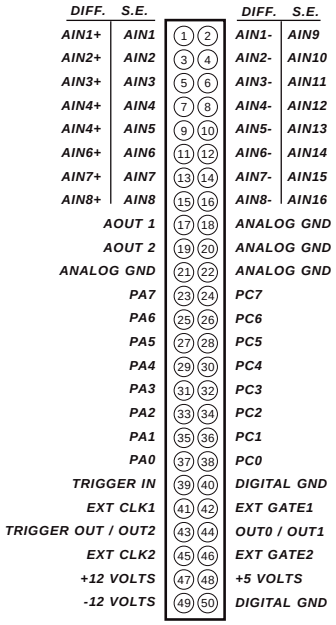

DIFF. S.E.
AIN1+ AIN1 1 2 AIN1- AIN9
AIN2+ AIN2 3 4 AIN2- AIN10
AIN3+ AIN3 5 6 AIN3- AIN11
AIN4+ AIN4 7 8 AIN4- AIN12
AIN4+ AIN5 9 10 AIN5- AIN13
AIN6+ AIN6 11 12 AIN6- AIN14
AIN7+ AIN7 13 14 AIN7- AIN15
AIN8+ AIN8 15 16 AIN8- AIN16
AOUT 1 17 18 ANALOG GND
AOUT 2 19 20 ANALOG GND
ANALOG GND 21 22 ANALOG GND
PA7 23 24 PC7
PA6 25 26 PC6
PA5 27 28 PC5
PA4 29 30 PC4
PA3 31 32 PC3
PA2 33 34 PC2
PA1 35 36 PC1
PA0 37 38 PC0
TRIGGER IN 39 40 DIGITAL GND
EXT CLK1 41 42 EXT GATE1
TRIGGER OUT / OUT2 43 44 OUT0 / OUT1
EXT CLK2 45 46 EXT GATE2
+12 VOLTS 47 48 +5 VOLTS
-12 VOLTS 49 50 DIGITAL GND

Fig. 2-1 — P2 I/O Connector Pin Assignments

Connecting the Analog Input Pins

16 Single-Ended. When operating in the 16 channel single-ended mode (P6-S), connect the high side of the analog inputs to the analog input channels, AIN1 through AIN16, and connect the low side to any of the ANALOG GND pins available at the connector (pins 18, 20-22 on P2). Ground any unused inputs. Figure 2-2 shows how these connections are made.

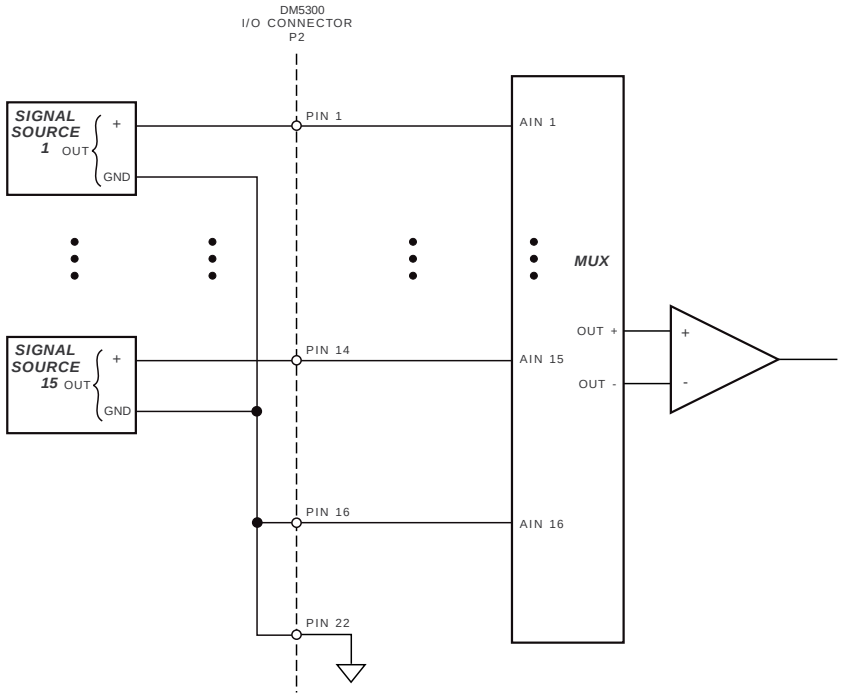


Fig. 2-2 — Single-Ended Input Connections

8 Differential. When operating in the differential mode (P6-D), twisted pair cable is recommended to reduce the effects of coupling at the input. Your signal source may or may not have a separate ground reference. When using the differential mode, you should install a 10 kilohm resistor pack at RN2 on the board to provide a reference to ground for signal sources without a separate ground reference.

Connect the high side of the analog input to the selected analog input channel, AIN1+ through AIN8+, and connect the low side to the corresponding AIN- pin. Then, for signal sources with a separate ground reference, connect the ground from the signal source to an ANALOG GND (pins 18 and 20-22 on P3). Figure 2-3 shows how these connections are made.

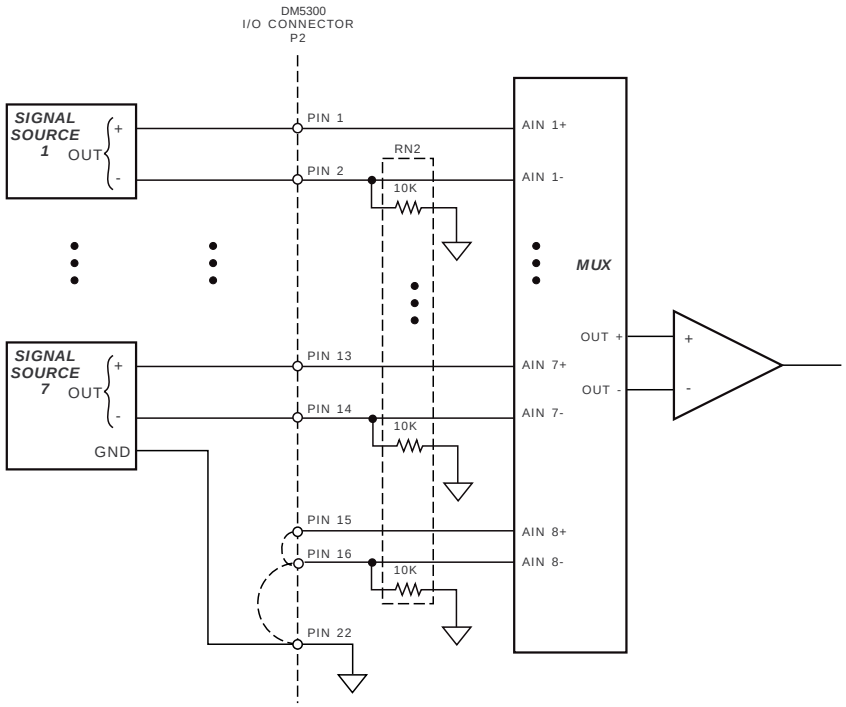


Fig. 2-3 — Differential Input Connections

Connecting the Trigger In and Trigger Out Pins, Cascading Modules

The DM5300 has an external trigger input (P2-39) and output (P2-43) so that two or more modules can be cascaded and run synchronously in a "master/slave" configuration. By cascading two (or more) modules as shown in Figure 2-5, they can be triggered to start an A/D conversion at the same time. Note that when using the external trigger output (P2-43) such as on the master module in Figure 2-4, you must set the jumper on P3 to TRIG.

If you apply an external trigger to the module's trigger in pin, note that the trigger can be negative- or positive-going. The pulse duration should be at least 100 nanoseconds. When using the TRIGGER OUT, the pulse must always be positive-going.

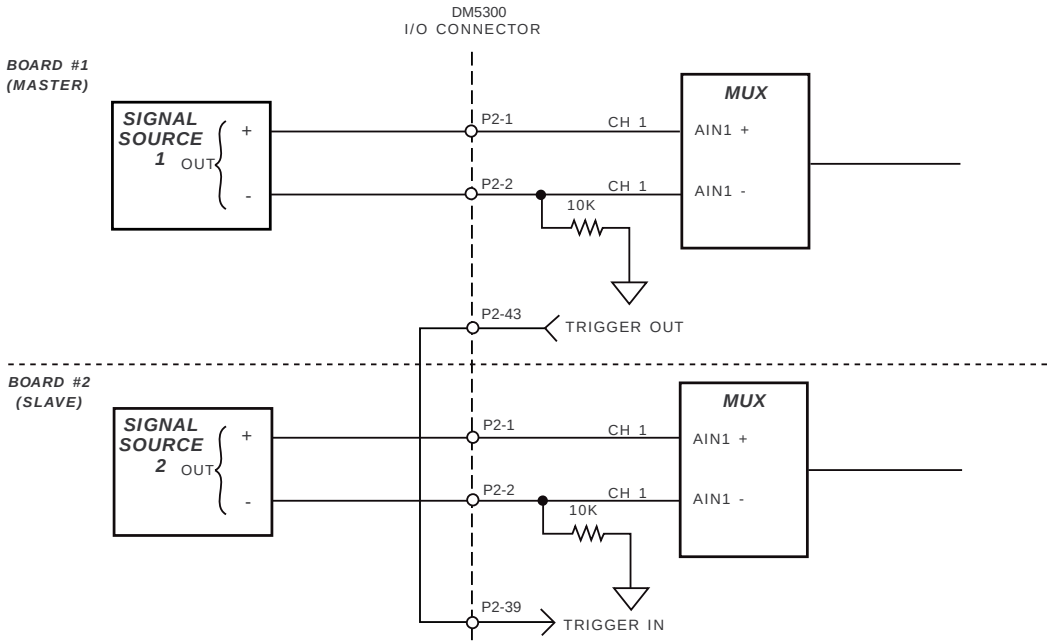


Fig. 2-4 — Cascading Two Modules for Simultaneous Sampling

Connecting the Analog Outputs

For each of the two D/A outputs, connect the high side of the device receiving the output to the AOUT channel (P2-17 or P2-19) and connect the low side of the device to an ANALOG GND (P2-18 or P2-20).

Connecting the Timer/Counters and Digital I/O

For all of these connections, the high side of an external signal source or destination device is connected to the appropriate signal pin on the I/O connector, and the low side is connected to any DIGITAL GND.

Running the 5300DIAG Diagnostics Program

Now that your module is ready to use, you will want to try it out. An easy-to-use, menu-driven diagnostics program, 5300DIAG, is included with your example software to help you verify your module's operation. You can also use this program to make sure that your current base address setting does not contend with another device.

CHAPTER 3 HARDWARE DESCRIPTION

This chapter describes the features of the DM5300 hardware. The major circuits are the A/D which consists of the V/F converter and associated timing and counting, the D/A, and the digital I/O lines. Three timer/counters from the user 8254 are available at the I/O connector for your use. Module interrupts are also described in this chapter.

The DM5300 has three major circuits, the A/D which consists of the V/F converter and associated timing and counting, the D/A, and the digital I/O lines. Three timer/counters from the user 8254 is available at the I/O connector for your use. Figure 3-1 shows the block diagram of the board. This chapter describes hardware which makes up the major circuits. It also discusses interrupts.

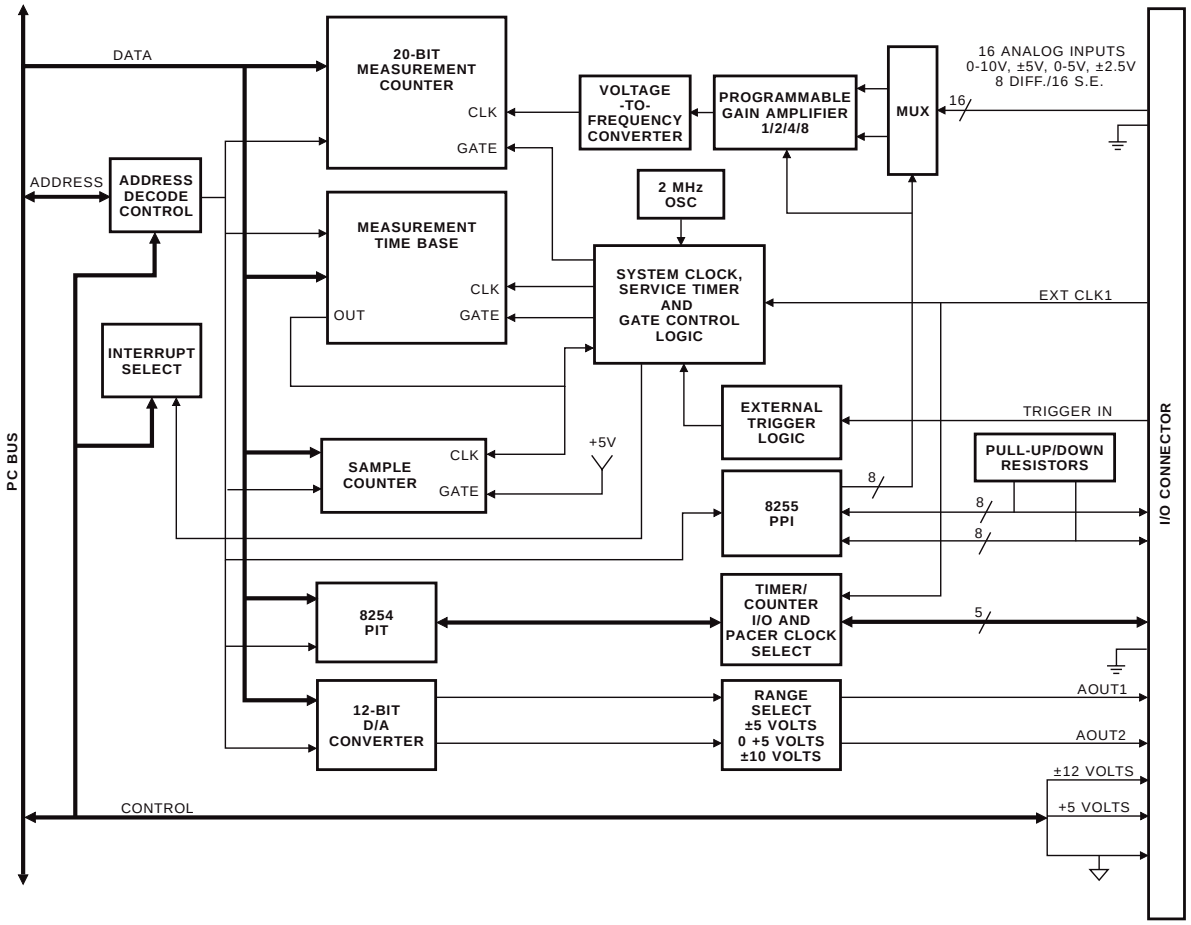


Fig. 3-1 — DM5300 Block Diagram

A/D Conversion Circuitry

The DM5300 performs analog-to-digital conversions using a voltage-to-frequency converter and timing and counting circuits. This circuitry functions as an exceptionally accurate integrating converter. The V/F converter converts the input voltage to a frequency between 0 and system clock ÷ 2 (full scale), and this frequency is counted by the frequency counter for a specified period of time. The following paragraphs describe the A/D circuitry.

Analog Inputs

The input type can be set for 8 differential or 16 single-ended by setting the jumpers on P6. Single-ended operation is typically used when the analog input voltage source is close to the module and the voltage levels are fairly high (greater than ±0.5 volts). The differential mode provides noise immunity when long cable runs are unavoidable, signal levels are low, or surrounding electrical noise is high. Software programmable binary gains of 1, 2, 4, and 8 let you amplify low level

signals to more closely match the module's input ranges. These gains can be customized for even greater input control by adding a gain multiplying resistor circuit as described in Chapter 1.

The input range is jumper-selectable for 5 volts or 10 volts, unipolar or bipolar. The available ranges are 0 to +5, 0 to +10, -2.5 to +2.5, and -5 to +5 volts. The module is factory set for -2.5 to +2.5 volts. Should you need to change the input range and/or polarity, you should recalibrate the board according to the instructions in Chapter 6, *Calibration*. Each channel has an input impedance of greater than 10 megohms. Overvoltage protection of ±35 Vdc is provided at the multiplexer.

V/F Converter

The V/F converter receives an input voltage and converts it to a corresponding frequency which is then read from the frequency counter as 20-bit data. The conversion time varies, depending on the degree of accuracy you want in your result and the speed of the system clock. The software selectable system clock can be set for 0.5, 1, or 2 MHz. A 1 MHz clock provides the best speed versus linearity tradeoff for most applications. At 0.5 MHz, linearity improves, but the conversion time doubles. A 2 MHz clock performs the fastest conversions, but sacrifices linearity. With a system clock of 1 MHz, a 12-bit conversion is performed in about 8 milliseconds, a 16-bit conversion in 131 milliseconds, and an 18-bit conversion in 524 milliseconds.

The V/F converter used on the DM5300 is Analog Devices' AD652 monolithic synchronous V/F converter. This extremely linear device is clocked by the programmable system clock. The system clock signal is divided by 2 on the chip, resulting in the 0 to system clock ÷ 2 frequency range of the converter. The same system clock is used to gate the timer circuitry, which means that you will get accurate conversions even if the clock frequency should drift.

To compensate for gain drift in the V/F converter, a trimpot is provided on the board. Chapter 6, *Calibration*, tells you how to adjust this trimpot.

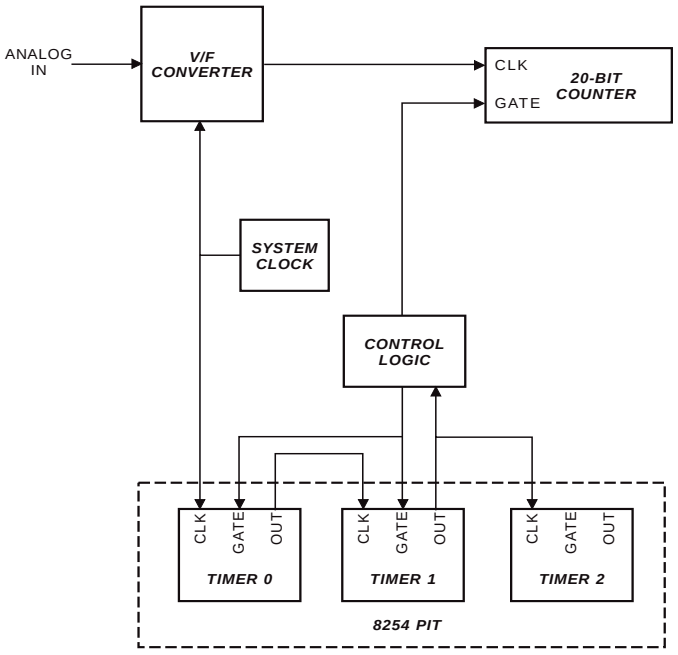


Fig. 3-2 — V/F Timing and Counting Block Diagram

Timing and Counting Circuits

The timing and counting circuits used with the V/F converter are shown in Figure 3-2. Very simply, the 8254 opens a window of time and the 20-bit counter counts the frequency output of the V/F converter.

The 20-bit counter has two flags: counter overflow and measurement overflow. The counter overflow flag is set if the 20-bit counter overflows within a single measurement cycle. The measurement overflow flag is set if two or more measurement cycles have been executed without the counter being cleared between cycles.

As shown in Figure 3-2, the 8254 programmable interval timer (PIT) contains three 16-bit timers. Two of these timers are cascaded to form a 32-bit timer which gates the frequency counters. The frequency counters are opened for a window of time specified by this 32-bit timer. You program the timer for the amount of time that you want the frequency counters to count, according to your desired resolution. The remaining timer in the 8254 (timer 2) can be used as a sample counter. The 8254 data sheet is included in Appendix C to assist you in using this timer.

A 20-bit counter is used to count the frequency output of the V/F converter for the period specified by the 8254 timer. For single conversions, a conversion is started, the 20-bit counter is gated for a specified period of time, and the value is read. For continuous conversions, the first conversion is started, the 20-bit counter is gated for a specified period of time, and, when the conversion is ready, the programmable service counter starts its countdown during which the converted data is read and the input channel and gain for the next conversion are set. When the service counter reaches 0, the next conversion is triggered.

D/A Converter

Two independent 12-bit analog output channels are included on the DM5300. The analog outputs are generated by two 12-bit D/A converters with independent jumper-selectable output ranges of ±5, ±10, 0 to +5, and 0 to +10 volts. The ±10 volt range has a resolution of 4.88 millivolts, the ±5 and 0 to +10 volt ranges have a resolution of 2.44 millivolts, and the 0 to +5 volt range has a resolution of 1.22 millivolts. The D/A outputs can be updated simultaneously or asynchronously.

Timer/Counters

Three 16-bit, 8 MHz timer/counters on the user 8254, TC0, TC1, and TC2, support a wide range of timing and counting functions. Each timer/counter has two inputs, CLK and GATE, and one output, OUT. Figure 3-3 shows the timer/counter circuitry and the connections you can make to the inputs and outputs. Each timer/counter can be programmed as binary or BCD down counters by writing the appropriate data to the command word, as described in Chapter 4. The command word also lets you set up the mode of operation. The six programmable modes are:

Mode 0	Event Counter (Interrupt on Terminal Count)
Mode 1	Hardware-Retriggerable One-Shot
Mode 2	Rate Generator
Mode 3	Square Wave Mode
Mode 4	Software-Triggered Strobe
Mode 5	Hardware Triggered Strobe (Retriggerable)

These modes are detailed in the 8254 Data Sheet, reprinted from Intel in Appendix C.

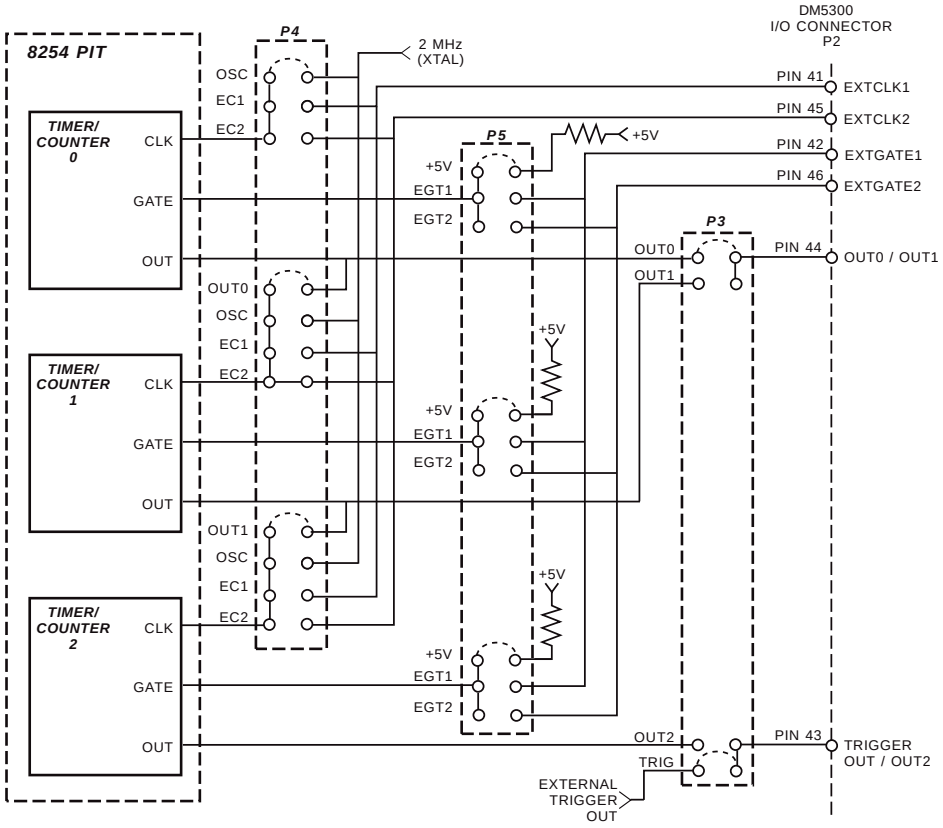


Fig. 3-3 — User 8254 Timer/Counter Circuitry

Digital I/O, Programmable Peripheral Interface

The 8255 programmable peripheral interface (PPI) is used for digital I/O functions. This high-performance TTL/CMOS compatible chip has 24 digital I/O lines divided into two groups of 12 lines each:

Group A — Port A (8 lines) and Port C Upper (4 lines);
Group B — Port B (8 lines) and Port C Lower (4 lines).

Port A and Port C are available at the external I/O connector, P2. Port B is dedicated to on-board functions and is not available for your use. You can use the 16 lines of Ports A and C in one of these three PPI operating modes:

Mode 0 — Basic input/output. Lets you use simple input and output operation for a port. Data is written to or read from the specified port.

Mode 1 — Strobed input/output. Lets you transfer I/O data from Port A in conjunction with strobes or handshaking signals.

Mode 2 — Strobed bidirectional input/output. Lets you communicate bidirectionally with an external device through Port A. Handshaking is similar to Mode 1.

These modes are detailed in the 8255 Data Sheet, reprinted from Intel in Appendix C.

Interrupts

The DM5300 has two software selectable interrupt sources: end-of-convert and external trigger. The end-of-convert (EOC) line can be used to interrupt the computer when a conversion is completed. When the 32-bit timer's count reaches 0, the counter gate closes, the conversion is complete, and the EOC line goes high. When in the continuous convert mode, the service time begins, and you can read the data, change the channel/gain settings, and reset the 20-bit counter. The EOC line can be connected through software, as shown in the I/O Map discussion in Chapter 4. On power-up, the IRQ line is disabled. Change the IRQ channel, if necessary, for your application. If you connect the end-of-convert to one of the interrupt channels, an interrupt will occur when the line transitions from low (converting) to high (not converting). The external trigger interrupt source is set by Jumper J4 selecting either the TRIGGER IN (P2-39) or the output of TIMER/COUNTER 2 (see page 1-10). When using the external trigger line as an external interrupt signal, the polarity (interrupt on rising or falling edge) is set at BA +21, bit 1. We recommend that you have an understanding of how to use interrupts in your system before you connect to an IRQ channel.

CHAPTER 4 MODULE OPERATION AND PROGRAMMING

This chapter tells you how to initialize the module and read the converted data. It describes operating modes and provides flow diagrams and a complete description of the I/O map to aid you in programming your DM5300. The example programs included on the disk in your board package are listed at the end of this chapter. These programs, written in BASIC and Turbo C, include source code to simplify your applications programming.

Chapter 5, *Calculating Frequencies, Voltages, and Bits*, contains tables, formulas, and examples to help you understand the principles of V/F conversion.

Defining the I/O Map

The I/O map for the DM5300 is shown in Table 4-1 below. As shown, the module occupies 23 consecutive I/O port locations. The base address (designated as BA) can be selected using DIP switch S1 as described in Chapter 1, *Module Settings*. This switch can be accessed without removing the module from the computer. S1 is factory set at 300 hex (768 decimal). The following sections describe the register contents of each address used in the I/O map.

Table 4.1 — DM5300 I/O Map

Register Description	Read Function	Write Function	Address* Decimal / (Hex)
A/D Data Low Byte	Read bottom 8 bits of 20-bit converted data word	Reserved	BA + 0 / (00)
A/D Data Middle Byte	Read middle 8 bits of 20-bit converted data word	Reserved	BA + 1 / (01)
A/D Data High Byte/Status	Read top 4 bits of 20-bit converted data word & status	Reserved	BA + 2 / (02)
Board Ready/Clear 20-bit Conversion Counter	Read board ready code	Clear the 20-bit conversion counter	BA + 3 / (03)
8254 Timer/Counter 0	Read count value	Load count register	BA + 4 / (04)
8254 Timer/Counter 1	Read count value	Load count register	BA + 5 / (05)
8254 Timer/Counter 2	Read count value	Load count register	BA + 6 / (06)
8254 Control Register	Reserved	Program 8254 mode	BA + 7 / (07)
8255 PPI Port A Digital I/O	Read 8-bit Port A digital input lines	Program 8-bit Port A digital output lines	BA + 8 / (08)
8255 PPI Port B (A/D Channel/Gain Select)	Read channel/gain settings	Program channel & gain	BA + 9 / (09)
8255 PPI Port C Digital I/O	Read 8-bit Port C digital input lines	Program 8-bit Port C digital output lines	BA + 10 / (0A)
8255 PPI Control Register	Reserved	Program 8255 configuration	BA + 11 / (0B)
DAC 1 Low Byte	Reserved	Program bottom 8 bits of 12-bit DAC 1 data	BA + 12 / (0C)
DAC 1 High Byte	Reserved	Program top 4 bits of 12-bit DAC 1 data	BA + 13 / (0D)
DAC 2 Low Byte	Reserved	Program bottom 8 bits of 12-bit DAC 2 data	BA + 14 / (0E)
DAC 2 High Byte	Reserved	Program top 4 bits of 12-bit DAC 2 data	BA + 15 / (0F)
8254 User Timer/Counter 0	Read count value	Load count register	BA + 16 / (10)
8254 User Timer/Counter 1	Read count value	Load count register	BA + 17 / (11)
8254 User Timer/Counter 2	Read count value	Load count register	BA + 18 / (12)
8254 Control Register	Reserved	Program 8254 mode	BA + 19 / (13)
Board Setup	Reserved	Program system clock, conversion mode and interrupt channel	BA + 20 / (14)
A/D Trigger Mode	Reserved	Program trigger mode and parameters	BA + 21 / (15)
Reset/Update DACs	Resets board	Simultaneously update DAC 1 and DAC 2	BA + 22 / (16)
*BA = Base Address			

BA + 0: A/D Data Low Byte (Read Only)

A read provides the low byte (bits 0 through 7) of the 20-bit converted data in the conversion counter.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

BA + 1: A/D Data Middle Byte (Read Only)

A read provides the middle byte (bits 8 through 15) of the 20-bit converted data in the conversion counter.

Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8
D7	D6	D5	D4	D3	D2	D1	D0

BA + 2: A/D Data High Byte (Read Only)

A read provides the high byte (bits 16 through 19) of the 20-bit converted data in the conversion counter, plus the counter overflow, measurement overflow, and conversion ready flag status. The counter overflow tells you if the 20-bit conversion counter overflows during a measurement cycle. The measurement overflow flag tells you if two or more measurement cycles are executed without clearing the counter between executions. The conversion ready flag tells you the conversion status (conversion running or conversion finished).

		X		Bit 19	Bit 18	Bit 17	Bit 16
D7	D6	D5	D4	D3	D2	D1	D0

A/D Conversion Status
0 = conversion running
1 = conversion complete

Measurement Overflow
0 = measurements OK
1 = 2 or more measurements without counter reset

Counter Overflow
0 = no overflow
1 = overflow

BA + 3: Board Ready/Clear 20-bit Conversion Counter (Read/Write)

A read must give you the value of 82 (52 hex) to indicate that the BA is set properly. A write clears the 20-bit conversion counter and flags. The data written is irrelevant.

BA + 4: 8254 Timer/Counter 0 (Read/Write)

Two reads show the count in the timer/counter, and two writes load the counter/timer with a new 16-bit value, LSB followed by MSB. The timer/counter must be loaded in two 8-bit steps. Counting begins as soon as the MSB is loaded.

This timer/counter, cascaded with timer/counter 1 to form a 32-bit timer, generates the module's internal pacer clock which controls measurements and starts and stops conversions.

BA + 5: 8254 Timer/Counter 1 (Read/Write)

Two reads show the count in the timer/counter, and two writes load the counter/timer with a new 16-bit value, LSB followed by MSB. The timer/counter must be loaded in two 8-bit steps. Counting begins as soon as the MSB is loaded.

This timer/counter, cascaded with timer/counter 0 to form a 32-bit timer, generates the module's internal pacer clock which controls measurements and starts and stops conversions.

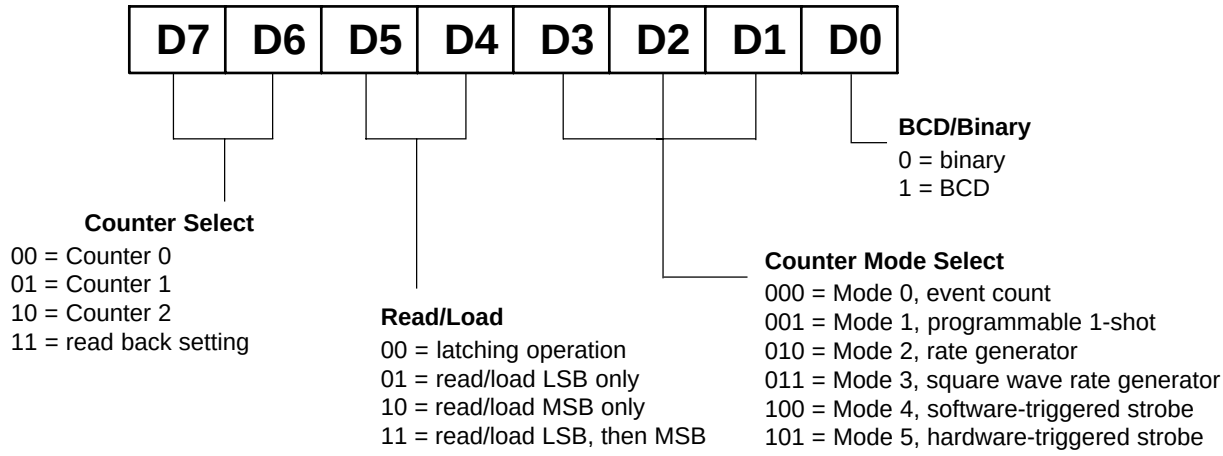
BA + 6: 8254 Timer/Counter 2 (Read/Write)

Two reads show the count in the timer/counter, and two writes load the counter/timer with a new 16-bit value, LSB followed by MSB. The timer/counter must be loaded in two 8-bit steps. Counting begins as soon as the MSB is loaded.

This timer/counter, with its clock input connected to the output of timer/counter 1, can be used as a sample counter to provide a hardware count of the number of samples being taken.

BA + 7: 8254 Control Word (Write Only)

Accesses the 8254 PIT control register to directly control the three timer/counters.



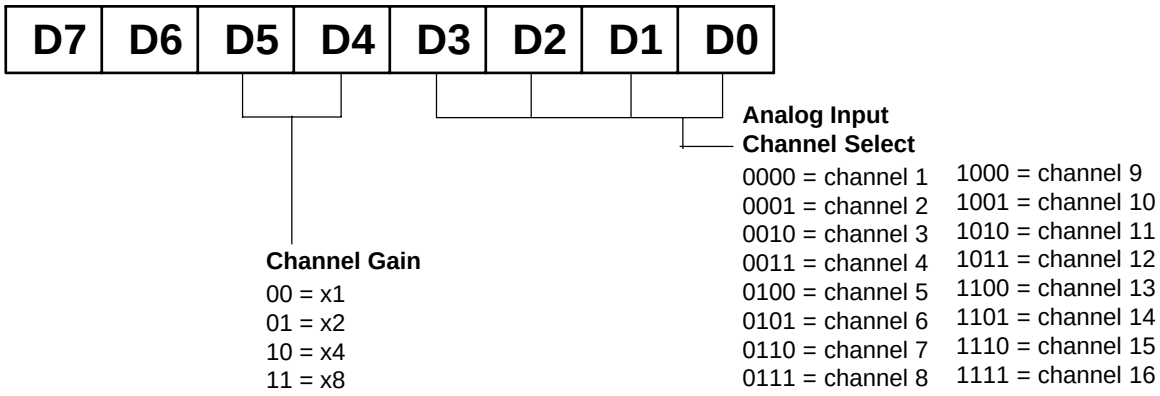
BA + 8: PPI Port A — Digital I/O (Read/Write)

Transfers the 8-bit Port A digital input and digital output data between the board and an external device. A read transfers data from the external device, through P2, and into PPI Port A; a write transfers the written data from Port A through P2 to an external device.

BA + 9: PPI Port B — Channel/Gain Select (Read/Write)

A write programs the analog input channel and gain for the next conversion. This port must be set up as a Mode 0 output for proper operation.

Reading this register shows you the current bit settings.

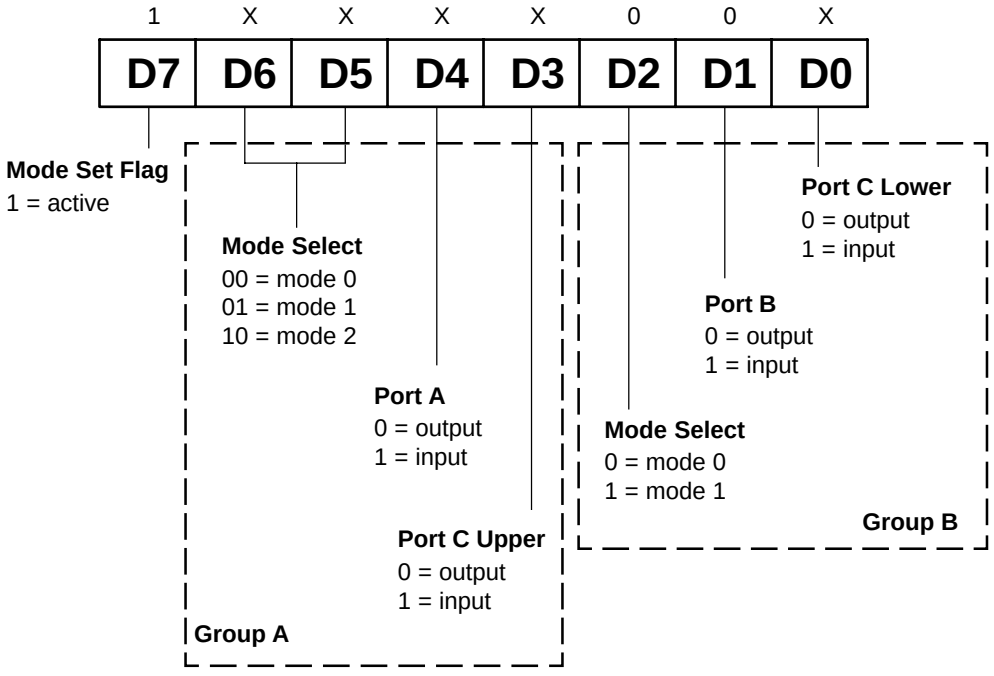


BA + 10: PPI Port C — Digital I/O (Read/Write)

Transfers the two 4-bit Port C digital input and digital output data groups (Port C Upper and Port C Lower) between the board and an external device. A read transfers data from the external device, through P2, and into PPI Port C; a write transfers the written data from Port C through P2 to an external device.

BA + 11: 8255 PPI Control Word (Write Only)

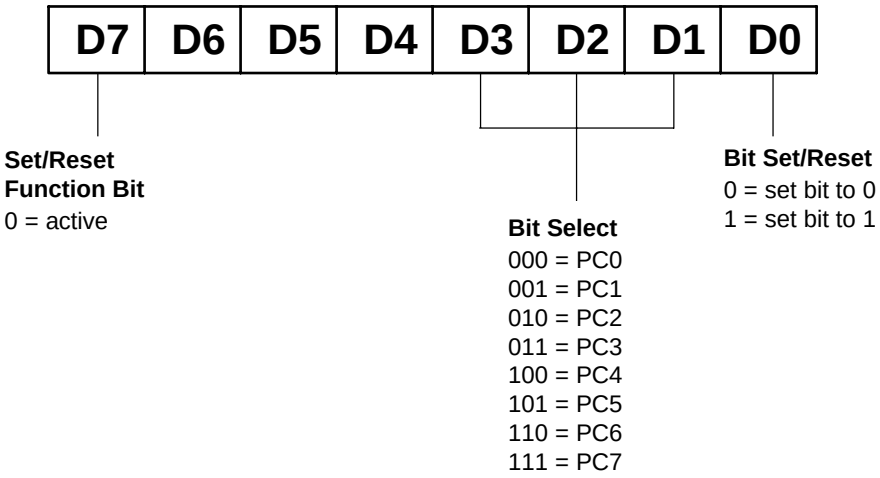
When bit 7 of this word is set to 1, a write programs the PPI configuration. The PPI must be programmed so that Port B is a Mode 0 output port, as shown below (X = don't care).



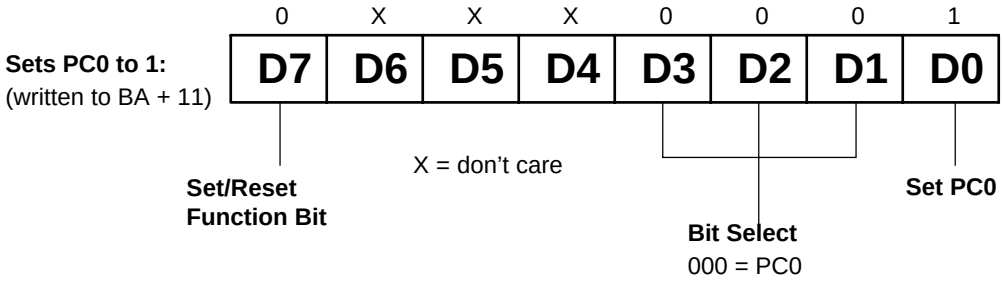
The table below shows the control words for the 16 possible Mode 0 Port I/O combinations. The control words which set Port B as an input cannot be used on the DM5300.

8255 Port I/O Flow Direction and Control Words, Mode 0						
Group A		Group B		Control Word		
Port A	Port C Upper	Port B	Port C Lower	Binary	Decimal	Hex
Output	Output	Output	Output	1 0 0 0 0 0 0 0	128	80
Output	Output	Output	Input	1 0 0 0 0 0 0 1	129	81
Output	Output	Input	Output	1 0 0 0 0 0 1 0	130	82
Output	Output	Input	Input	1 0 0 0 0 0 1 1	131	83
Output	Input	Output	Output	1 0 0 0 1 0 0 0	136	88
Output	Input	Output	Input	1 0 0 0 1 0 0 1	137	89
Output	Input	Input	Output	1 0 0 0 1 0 1 0	138	8A
Output	Input	Input	Input	1 0 0 0 1 0 1 1	139	8B
Input	Output	Output	Output	1 0 0 1 0 0 0 0	144	90
Input	Output	Output	Input	1 0 0 1 0 0 0 1	145	91
Input	Output	Input	Output	1 0 0 1 0 0 1 0	146	92
Input	Output	Input	Input	1 0 0 1 0 0 1 1	147	93
Input	Input	Output	Output	1 0 0 1 1 0 0 0	152	98
Input	Input	Output	Input	1 0 0 1 1 0 0 1	153	99
Input	Input	Input	Output	1 0 0 1 1 0 1 0	154	9A
Input	Input	Input	Input	1 0 0 1 1 0 1 1	155	9B

When bit 7 of the PPI control word is set to 0, a write can be used to individually program the Port C lines.



For example, if you want to set Port C bit 0 to 1, you would set up the control word so that bit 7 is 0; bits 1, 2, and 3 are 0 (this selects PC0); and bit 0 is 1 (this sets PC0 to 1). The control word is set up like this:



BA + 12: D/A Converter 1 LSB (Read/Write)

A write programs the DAC1 LSB (eight bits).

BA + 13: D/A Converter 1 MSB (Read/Write)

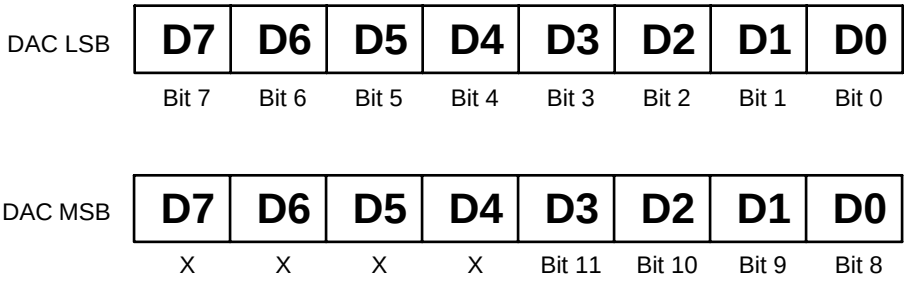
A write programs the DAC1 MSB (four bits) into D0 through D3; D4 through D7 are irrelevant.

BA + 14: D/A Converter 2 LSB (Read/Write)

A write programs the DAC2 LSB (eight bits).

BA + 15: D/A Converter 2 MSB (Read/Write)

A write programs the DAC2 MSB (four bits) into D0 through D3; D4 through D7 are irrelevant.



BA + 16: User 8254 Timer/Counter 0 (Read/Write)

Two reads show the count in the timer/counter, and two writes load the counter/timer with a new 16-bit value, LSB followed by MSB. The timer/counter must be loaded in two 8-bit steps. Counting begins as soon as the MSB is loaded.

BA + 17: User 8254 Timer/Counter 1 (Read/Write)

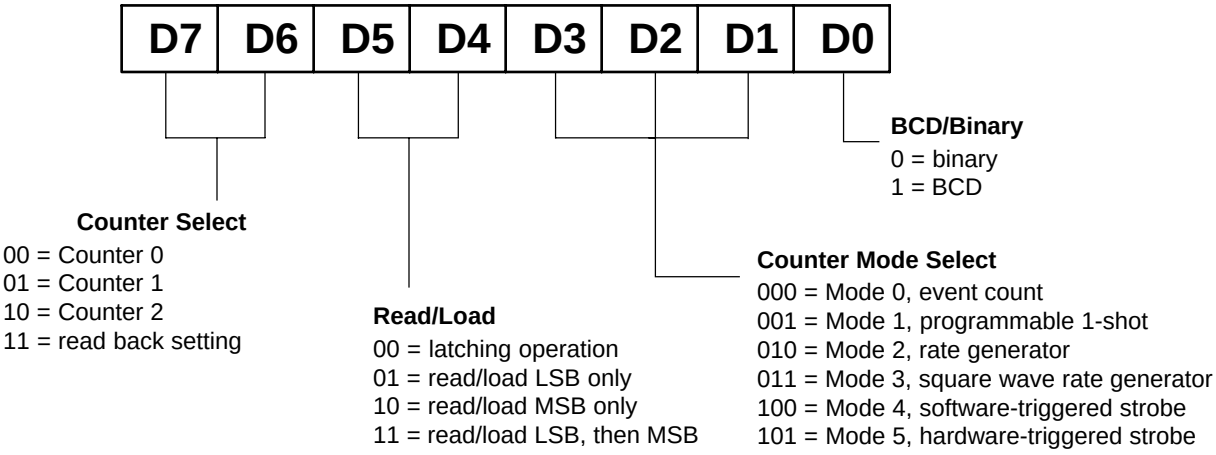
Two reads show the count in the timer/counter, and two writes load the counter/timer with a new 16-bit value, LSB followed by MSB. The timer/counter must be loaded in two 8-bit steps. Counting begins as soon as the MSB is loaded.

BA + 18: User 8254 Timer/Counter 2 (Read/Write)

Two reads show the count in the timer/counter, and two writes load the counter/timer with a new 16-bit value, LSB followed by MSB. The timer/counter must be loaded in two 8-bit steps. Counting begins as soon as the MSB is loaded.

BA + 19: User 8254 Control Word (Write Only)

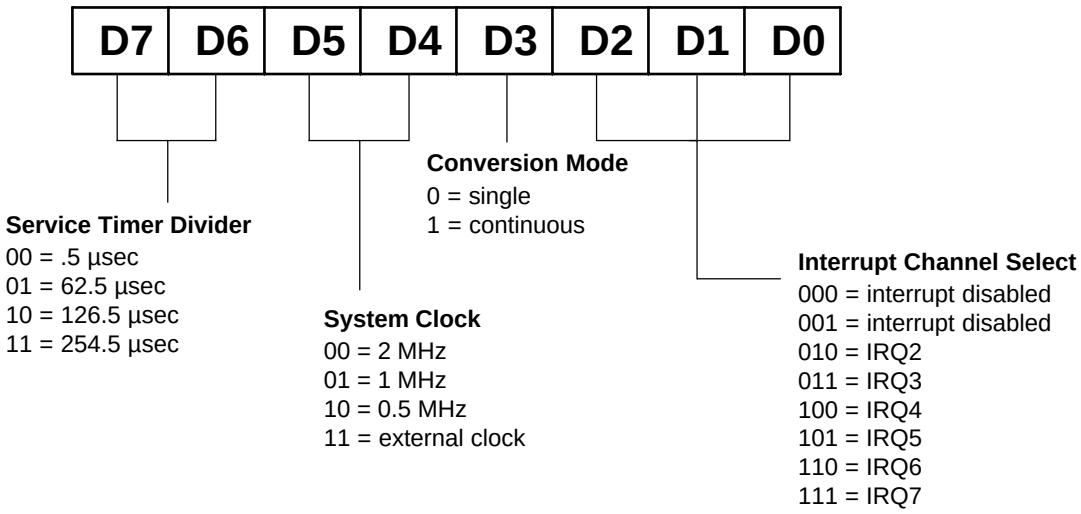
Accesses the 8254 PIT control register to directly control the three user timer/counters.


D7 D6 D5 D4 D3 D2 D1 D0
BCD/Binary
0 = binary
1 = BCD
Counter Select
00 = Counter 0
01 = Counter 1
10 = Counter 2
11 = read back setting
Read/Load
00 = latching operation
01 = read/load LSB only
10 = read/load MSB only
11 = read/load LSB, then MSB
Counter Mode Select
000 = Mode 0, event count
001 = Mode 1, programmable 1-shot
010 = Mode 2, rate generator
011 = Mode 3, square wave rate generator
100 = Mode 4, software-triggered strobe
101 = Mode 5, hardware-triggered strobe

BA + 20: Board Setup Register (Write Only)

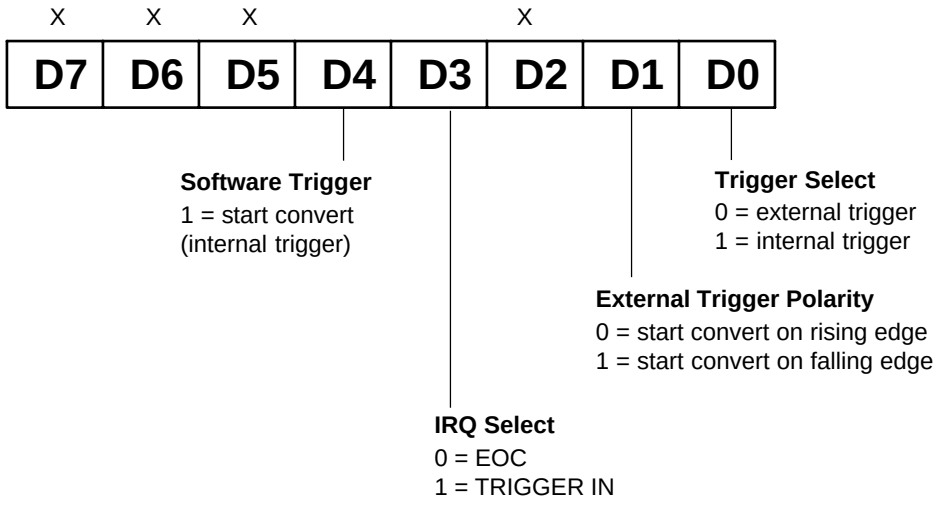
A write sets the PC's interrupt channel, the A/D conversion mode, the system clock speed, and the service timer divider. Bits 0 through 2 are used to select the interrupt channel. Two settings, 000 and 001, disable the interrupt. If an IRQ channel is programmed, the interrupt selected at BA +21 is automatically enabled on that channel.

The service time is programmable to provide you with as much time as you need to read the data, clear the counter, and change the channel and gain.



BA + 21: A/D Trigger Mode Register (Write Only)

This register sets up various triggering parameters for conversions. Bit 0 sets the trigger mode, internal or external. In the external trigger mode, a conversion can be started on the rising or falling edge of the trigger, depending on the setting of bit 1. Bit 3 sets the interrupt source (see the discussion about J4 on page 1-10). Bit 4 can be used to start a conversion in internal trigger mode. In the single conversion mode, only one measurement is taken. In the continuous mode, after the start, the board is continuously converting. To stop continuous conversions, program the conversion mode to single at BA +20.


X X X X
D7 D6 D5 D4 D3 D2 D1 D0
Software Trigger
1 = start convert
(internal trigger)
IRQ Select
0 = EOC
1 = TRIGGER IN
External Trigger Polarity
0 = start convert on rising edge
1 = start convert on falling edge
Trigger Select
0 = external trigger
1 = internal trigger

BA + 22: Reset/Update DACs (Read/Write)

A read resets the module. The data written is irrelevant.

A write simultaneously updates the two D/A outputs with the latched data. If the data written to either channel has not been updated since the last conversion, the output of the corresponding DAC will not change.

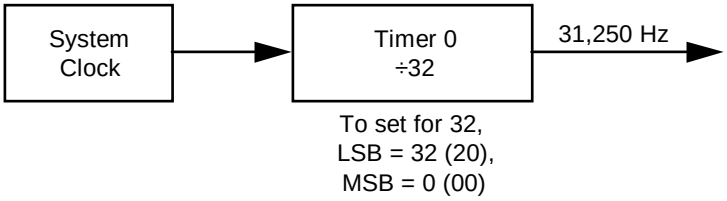
A/D Conversions

Before you can start taking A/D conversions, you must clear the 20-bit counter and program the 8254 timer. The software provided with your board contains example programs for module initialization.

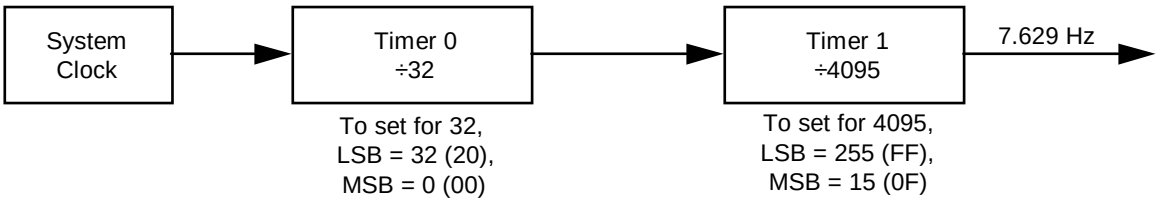
You can monitor the conversion status using the end-of-convert bit at I/O address location BA + 2. When bit 7 of this word is low, a conversion is in progress. When it goes high, the conversion is completed. Note that the end-of-convert line can also be monitored through a software programmable IRQ line if it is enabled.

Programming the 8254 Timer

Two of the 8254's 16-bit timers are cascaded to form a 32-bit timer which gates the 20-bit conversion counter. The timer is clocked by the same system clock which supplies the V/F converter. Timer 0 and timer 1 are programmed with the values that will open the conversion gate for the desired time window. In the example programs included with your module, timer 0 is always set at 32. This divides the input frequency of system clock by 32, which produces an output frequency of system clock ÷ 32 going into timer 1. For a system clock of 1 MHz, this is:



Then, timer 1 is programmed with the correct divider value to take readings at the desired resolution. For example, if you want a resolution of 16 bits with the system clock programmed to run at 1 MHz, then you must program timer 1 to further divide the output of timer 0 by 4095. This produces an output frequency of 7.629 Hz, which will open the 20-bit conversion counter gate for 131.072 milliseconds giving you a 16-bit resolution:



NOTE: The above example is for both single and continuous conversions. Note that you must always subtract 1 from the value you load into timer 1 in order to have an accurate count. This is done to compensate for how the 8254 handles single countdown operations for cascaded timers. In the continuous mode, the sampling rate is determined by:

fs = 1 ÷ (gate time + service time).

As you can see, the timing calculations can be somewhat complex. The formulas for calculating the counts to load into the timers are given in Chapter 5. Chapter 5 also provides tables and formulas for decimal counts. These are helpful for voltage-based resolutions, such as a resolution of 100 microvolts. Here, you can refer to the following table to help you determine the count to be loaded into the timers for bit-based resolutions.

Resolution	Timer 0 LSB (Decimal/Hex)	Timer 0 MSB (Decimal/Hex)	Timer 1 LSB (Decimal/Hex)	Timer 1 MSB (Decimal/Hex)
12 bits	32 / 20	0 / 00	255 / FF	0 / 00
13 bits	32 / 20	0 / 00	255 / FF	1 / 01
14 bits	32 / 20	0 / 00	255 / FF	3 / 03
15 bits	32 / 20	0 / 00	255 / FF	7 / 07
16 bits	32 / 20	0 / 00	255 / FF	15 / 0F
17 bits	32 / 20	0 / 00	255 / FF	31 / 1F
18 bits	32 / 20	0 / 00	255 / FF	63 / 3F

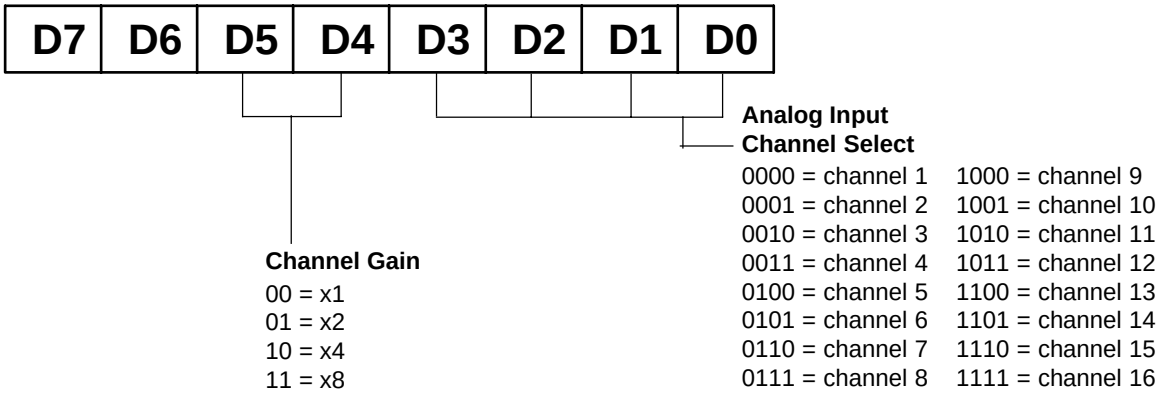
This chapter's final example for the 8254 timer is a portion of an initialization program, written in BASIC, which shows you how to set up the 8254 timers 0 and 1 so that they open the conversion counter for a time period of 131.072 milliseconds, giving you a 16-bit resolution with a 1 MHz system clock. The timer 1 divider is 4095. In this example, TWC stands for the 8254 control register which is addressed at BA + 7 (decimal), TA stands for timer 0 which is addressed at BA + 4, and TB stands for timer 1 which is addressed at BA + 5. All values are in hex.

```
OUT TWC, &H34      'SET UP TIMER 0 AS MODE 2
OUT TWC, &H74      'SET UP TIMER 1 AS MODE 2
OUT TA, &H20       'SET TIMER 0 DIVIDER LSB (LSB=32 FOR DIVIDER OF 32)
OUT TA, &H0        'SET TIMER 0 DIVIDER MSB (MSB=0 FOR DIVIDER OF 0)
OUT TB, &HFF       'SET TIMER 1 DIVIDER LSB (LSB=255 FOR DIVIDER OF 255)
OUT TB, &HF        'SET TIMER 1 DIVIDER MSB (MSB=15 FOR DIVIDER OF 15)
```

Initializing the 8255 PPI

The eight Port B lines of the 8255 PPI control the channel and gain selection. Port B is programmed at I/O address location BA + 9:

To use Port B for these functions, the 8255 must be initialized so that Port B is set up as a Mode 0 output port. This is done by writing this data to the PPI control word at I/O address BA + 11 (X =



don't care):

Clearing the Module

1	X	X	X	X	0	0	X
D7	D6	D5	D4	D3	D2	D1	D0

It is good practice to start your program by resetting the module. You can do this by performing a read of the RESET port at BA + 22.

Setting the Channel

To select a conversion channel, you must assign the appropriate values to bits 0 through 3 at BA + 9. The table below shows you how to determine the bit settings. Note that if you don't want to change the gain setting when programming a new channel setting, you must preserve the gain portion of the channel-gain data when you set the channel.

X	X	X	X	CH3	CH2	CH1	CH0	BA + 9

Channel	CH3	CH2	CH1	CH0	Channel	CH3	CH2	CH1	CH0
1	0	0	0	0	9	1	0	0	0
2	0	0	0	1	10	1	0	0	1
3	0	0	1	0	11	1	0	1	0
4	0	0	1	1	12	1	0	1	1
5	0	1	0	0	13	1	1	0	0
6	0	1	0	1	14	1	1	0	1
7	0	1	1	0	15	1	1	1	0
8	0	1	1	1	16	1	1	1	1

Setting the Gain

To select the gain (1, 2, 4, or 8), you must assign the appropriate values to bits 4 and 5 at BA + 9. The table below shows you how to determine the bit settings. Note that if you don't want to change the channel setting when programming a new gain setting, you must preserve the channel portion of the channel-gain data when you set the gain.

x	x	G1	G0	x	x	x	x	BA + 9

Gain	G1	G0
1	0	0
2	0	1
4	1	0
8	1	1

Conversion Modes

The A/D circuitry can perform conversions in two modes, *Single Convert* and *Continuous Convert*.

Single Convert Mode

The *Single Convert* mode lets you perform a single A/D conversion each time you write a 1 to the Software Trigger (Start Convert) bit, bit 4 at BA + 21. BA + 20, bit 3 should be set to 0 for single conversions. Figure 4-1 shows the timing diagram for this mode, and Figure 4-2 provides a flow diagram.

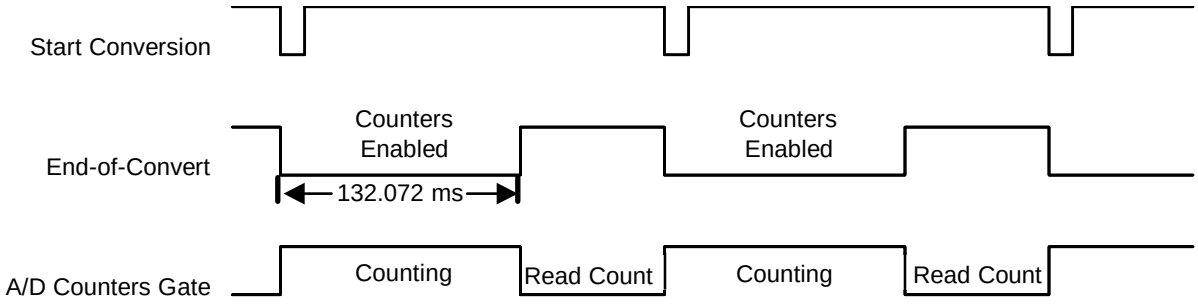


Fig. 4-1 — Single Convert Mode Timing Diagram

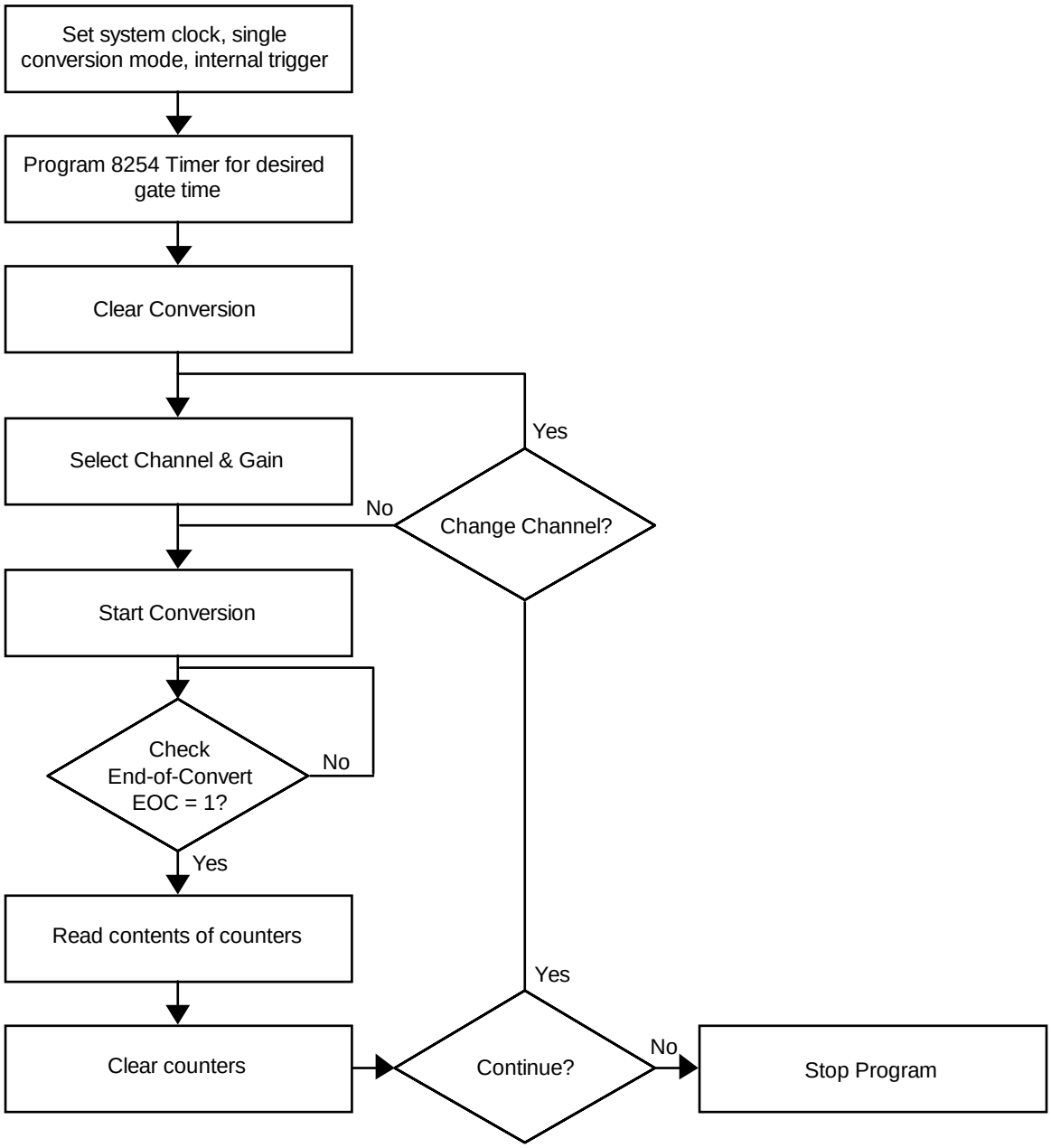


Fig. 4-2 — Single Convert Mode Flow Diagram

Continuous Convert Mode

The *Continuous Convert* mode lets you perform continuous conversions by writing a 1 to the Software Trigger (Start Convert) bit, bit 4 at BA + 21. BA + 20, bit 3 should be set to 1 for continuous conversions. Figure 4-3 shows the timing diagram for this mode, and Figure 4-4 provides a flow diagram.

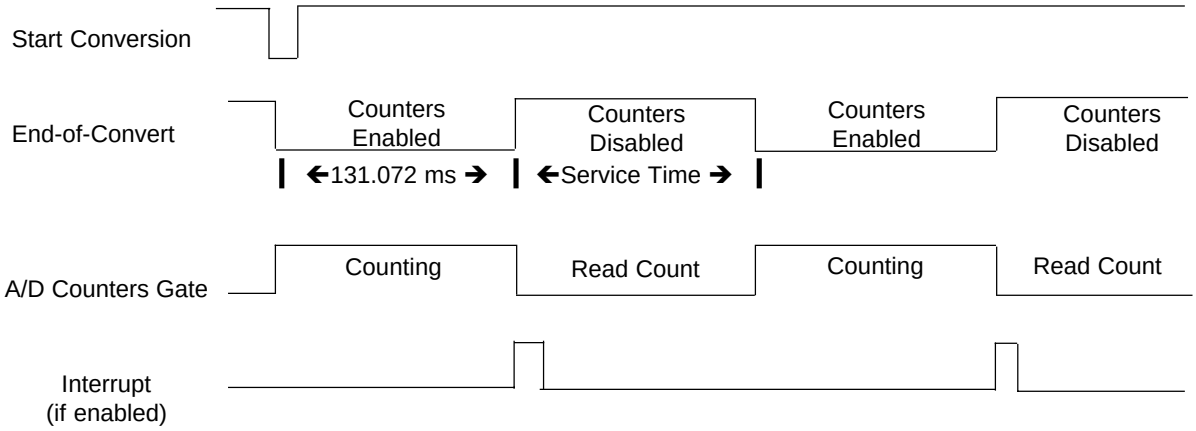


Fig. 4-3 — Continuous Convert Mode Timing Diagram

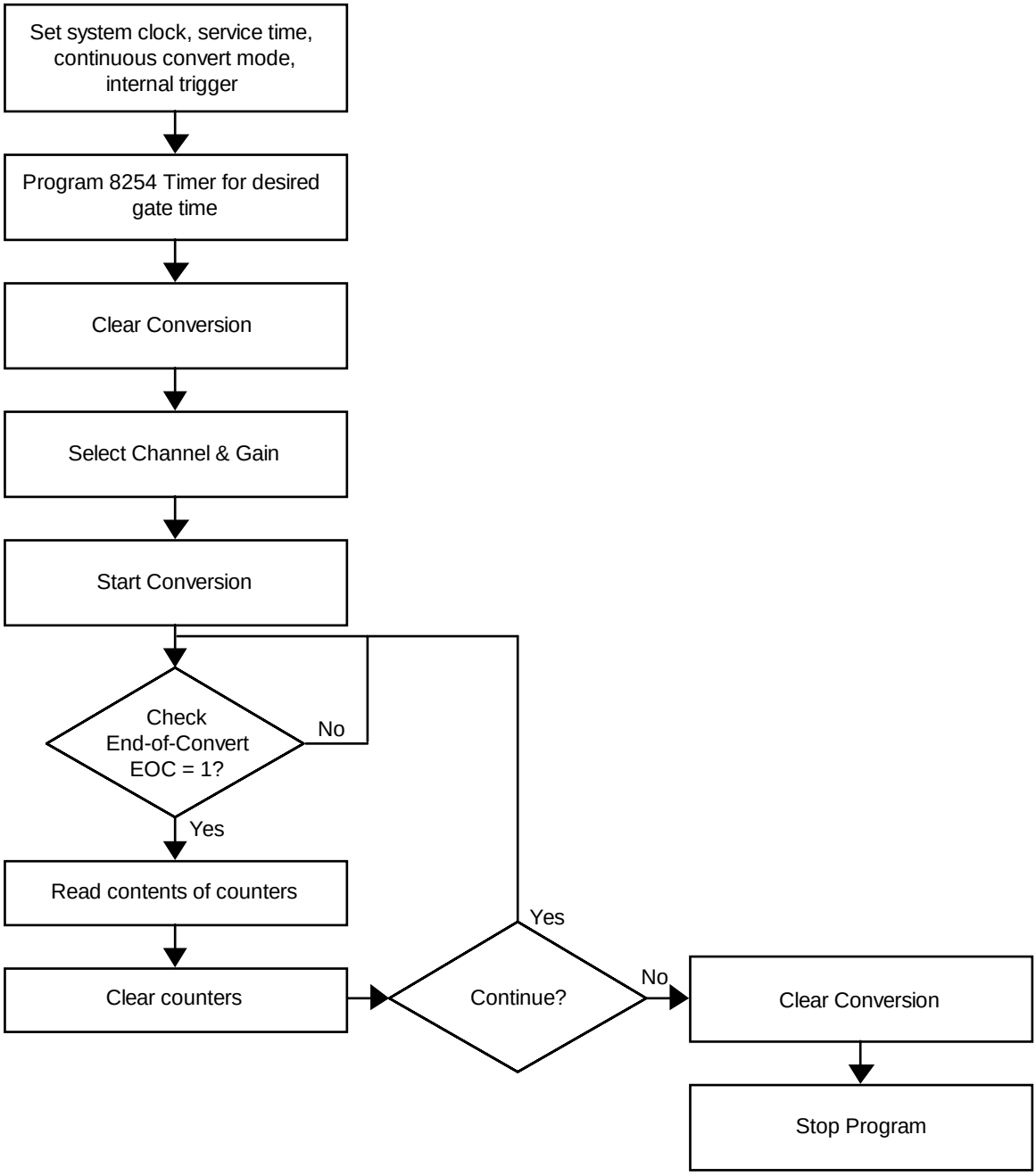


Fig. 4-4 — Continuous Convert Mode Flow Diagram

Cascading Modules

Two or more modules can be cascaded and triggered so that conversions are performed simultaneously on each module. Figure 4-5 provides a flow diagram for cascaded operation. Chapter 2 shows how to connect the modules for simultaneous triggering.

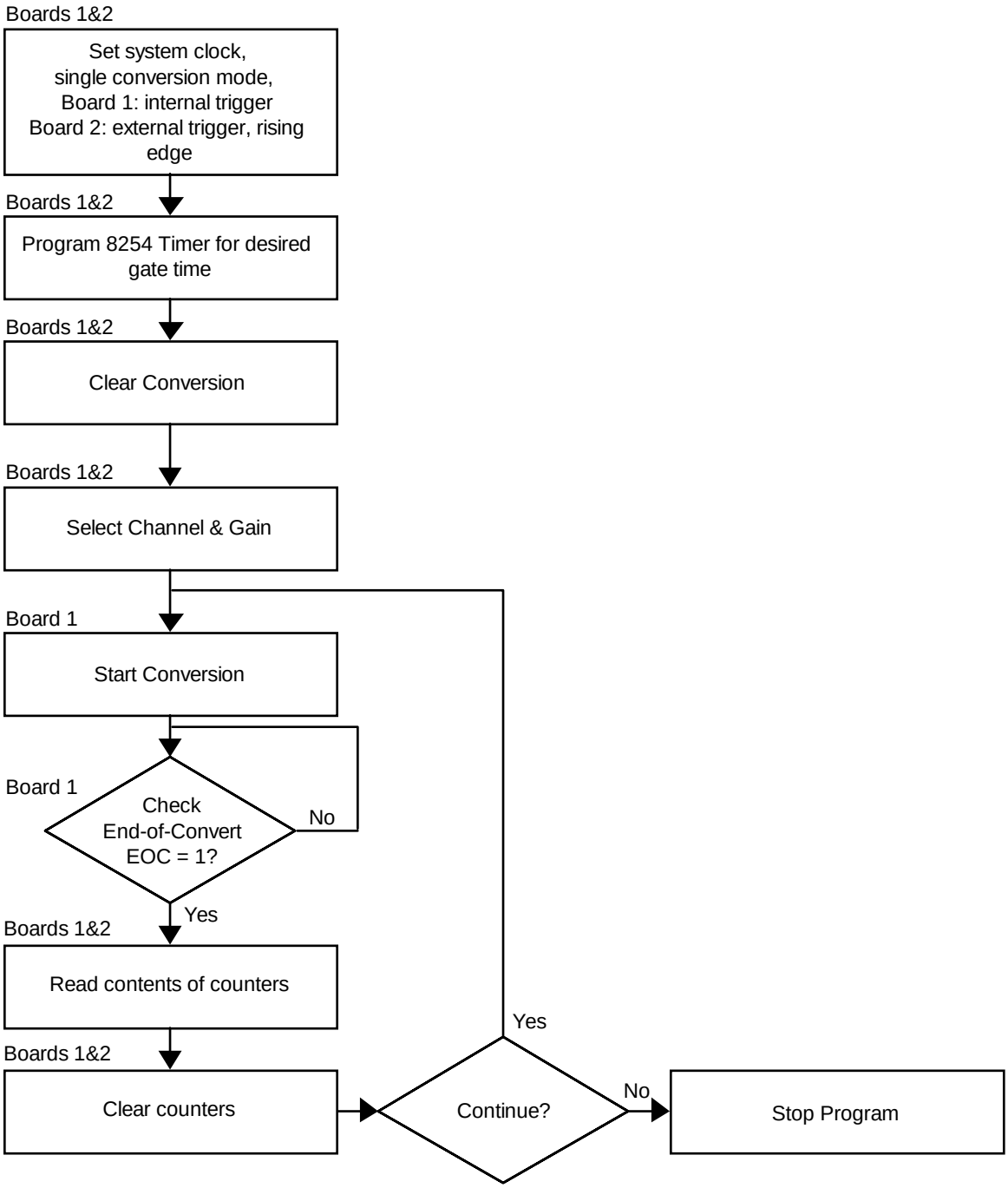


Fig. 4-5 — Cascaded Modules, Single Convert Mode Flow Diagram

Reading the Converted Data

After a conversion is completed, the data is read from the 20-bit conversion counter. The excerpt below from an example BASIC program shows you how data is read from the counter. The data is read in three bytes, the low, middle, and high byte, at three I/O address locations, BA + 0, BA + 1, and BA + 2. The upper half of the byte contains the status bit of the measurement. You must mask this bit out before using the value.

```
ADLB = INP(BA)               'READ COUNTER LOW BYTE
ADMB = INP(BA + 1)           'READ COUNTER MIDDLE BYTE
ADHB = INP(BA + 2) AND 0HE   'READ COUNTER HIGH BYTE
RESULT = ((ADLB + (ADMB x 256) + (ADHB x 65536)) x CF
```

The last line of this example program shows you how to convert the result into the true frequency output by the V/F converter. After performing the multiplication by the bit weight for each of the four bytes read, you must then multiply the result by a correction factor, CF, in order to find the true frequency of the signal you measured. The correction factor is the inverse of the amount of time you had the counter gated open for counting
(CF = 1 ÷ Gate Time).

For example, if you count a 10 Hz signal for 1 second, your count would be 10. This is multiplied by a correction factor of 1, which is 1 ÷ 1 second. If you count the same 10 Hz signal for 0.5 seconds, your count would be 5. This is multiplied by a correction factor of 2 (1 ÷ 0.5 seconds) which again gives you the true frequency of 10 Hz. Counting 10 Hz for 2 seconds gives you a count of 20 which is then multiplied by a correction factor of 0.5 (1 ÷ 2 seconds) for a result of 10 Hz. In contrast, a more complex example is counting for 131.072 milliseconds (a 16-bit resolution). The correction factor is 1 ÷ .131072, or 7.629.

D/A Conversions

The two D/A converters can be individually programmed to convert 12-bit digital words into a voltage in the range of ±5, ±10, 0 to +5, or 0 to +10 volts. DAC1 is programmed by writing the 12-bit digital data word to BA + 8 and BA + 9. DAC2 is identical, with the data word written to BA + 10 and BA + 11. The DACs are updated by writing to BA + 22. The following tables list the key digital codes and corresponding output voltages for the D/A converters.

D/A Converter Unipolar Calibration Table		
	Ideal Output Voltage (in millivolts)	
D/A Bit Weight	0 to +5 V	0 to +10 V
4095 (Max. Output)	4998.8	9997.6
2048	2500.0	5000.0
1024	1250.0	2500.0
512	625.0	1250.0
256	312.50	625.00
128	156.250	312.50
64	78.125	156.250
32	39.063	78.125
16	19.5313	39.063
8	9.7656	19.5313
4	4.8828	9.7656
2	2.4414	4.8828
1	1.2207	2.4414
0	0.0000	0.0000

D/A Converter Bipolar Calibration Table		
	Ideal Output Voltage (in millivolts)	
D/A Bit Weight	±5 V	±10 V
4095 (Max. Output)	+4997.6	+9995.1
2048	0.0	0.0
1024	-2500.0	-5000.0
512	-3750.0	-7500.0
256	-4375.0	-8750.0
128	-4687.5	-9375.0
64	-4843.8	-9687.5
32	-4921.9	-9843.8
16	-4960.9	-9921.9
8	-4980.5	-9960.9
4	-4990.2	-9980.5
2	-4995.1	-9990.2
1	-4997.6	-9995.1
0	-5000.0	-10000.0

User-Available 8254 Timer/Counter

An 8254 programmable interval timer provides three 16-bit, 8 MHz timer/counters for timing and counting functions such as frequency measurement, event counting, and interrupts. All three timer/counters are available for your use. Figure 4-6 shows the timer/counter circuitry.

Each timer/counter has two inputs, CLK in and GATE in, and one output, timer/counter OUT. They can be programmed as binary or BCD down counters by writing the appropriate data to the command word, as described in the I/O map section at the beginning of this chapter.

One of three clock sources, the on-board 2 MHz crystal, external clock 1 (EXT CLK1, P2-41), or external clock 2 (EXT CLK2, P2-45) can be selected as the clock input. The diagram shows how these clock sources are connected to the timer/counters.

Three gate sources are available: +5V on-board (always tied high), external gate 1 (EXT GATE1, P2-42), or external gate 2 (EXT GATE2, P2-46). The diagram shows how these gate sources are connected to the timer/counters.

The output from timer/counter 0 or 1 is jumper-selectable. The selected output is available at the OUT0/OUT1 pin (P2-44). Timer/counter 2's output is available at the TRIGGER OUT/OUT2 (P2-43) if it is enabled by placing the jumper on P3 across the appropriate pins. The diagram shows how these outputs are connected.

The timer/counters can be programmed to operate in one of six modes, depending on your application. The following paragraphs briefly describe each mode.

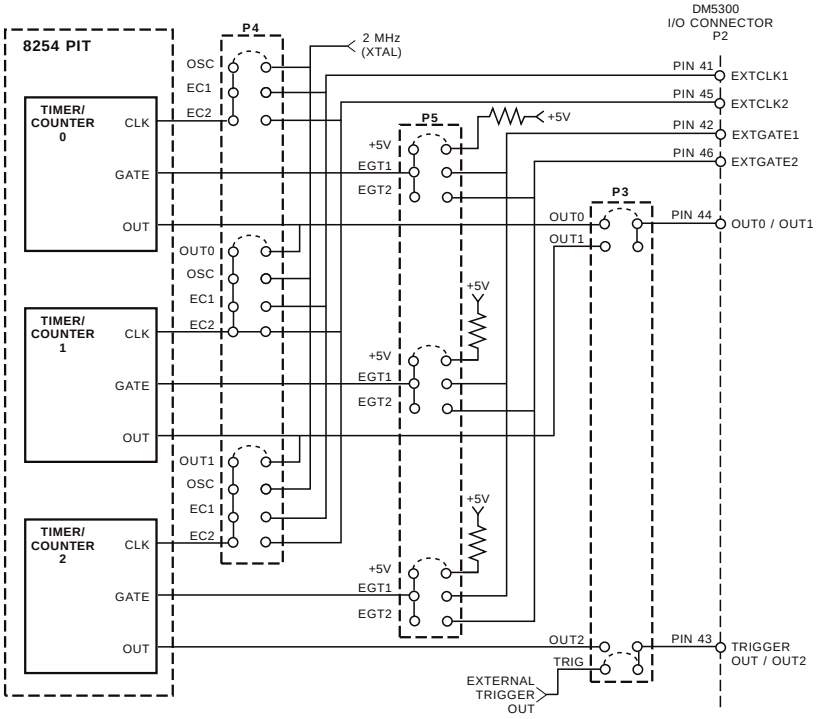


Fig. 4-6 — User 8254 Timer/Counter Circuitry

Mode 0, Event Counter (Interrupt on Terminal Count). This mode is typically used for event counting. While the timer/counter counts down, the output is low, and when the count is complete, it goes high. The output stays high until a new Mode 0 control word is written to the timer/counter.

Mode 1, Hardware-Retriggerable One-Shot. The output is initially high and goes low on the clock pulse following a trigger to begin the one-shot pulse. The output remains low until the count reaches 0, and then goes high and remains high until the clock pulse after the next trigger.

Mode 2, Rate Generator. This mode functions like a divide-by-N counter and is typically used to generate a real-time clock interrupt. The output is initially high, and when the count decrements to 1, the output goes low for one clock pulse. The output then goes high again, the timer/counter reloads the initial count, and the process is repeated. This sequence continues indefinitely.

Mode 3, Square Wave Mode. Similar to Mode 2 except for the duty cycle output, this mode is typically used for baud rate generation. The output is initially high, and when the count decrements to one-half its initial count, the output goes low for the remainder of the count. The timer/counter reloads and the output goes high again. This process repeats indefinitely.

Mode 4, Software-Triggered Strobe. The output is initially high. When the initial count expires, the output goes low for one clock pulse and then goes high again. Counting is “triggered” by writing the initial count.

Mode 5, Hardware Triggered Strobe (Retriggerable). The output is initially high. Counting is triggered by the rising edge of the gate input. When the initial count has expired, the output goes low for one clock pulse and then goes high again.

Digital I/O

The 16 8255 PPI-based digital I/O lines can be used to transfer data between the computer and external devices. The digital input lines can have pull-up or pull-down resistors installed, as described in Chapter 1.

Interrupts

The DM5300 has two software selectable interrupt sources: end-of-convert and external trigger. The end-of-convert (EOC) line can be used to interrupt the computer when a conversion is completed. When the 32-bit timer's count reaches 0, the counter gate closes, the conversion is complete, and the EOC line goes high. When in the continuous convert mode, the service time begins, and you can read the data, change the channel/gain settings, and reset the 20-bit counter. The EOC line can be connected through software, as shown in the I/O Map discussion in Chapter 4. On power-up, the IRQ line is disabled. Change the IRQ channel, if necessary, for your application. If you connect the end-of-convert to one of the interrupt channels, an interrupt will occur when the line transitions from low (converting) to high (not converting). The external trigger interrupt source is set by Jumper J4 selecting either the TRIGGER IN (P2-39) or the output of TIMER/COUNTER 2 (see page 1-10). When using the external trigger line as an external interrupt signal, the polarity (interrupt on rising or falling edge) is set at BA +21, bit 1. We recommend that you have an understanding of how to use interrupts in your system before you connect to an IRQ channel.

Example Programs

Included with the DM5300 is a set of example programs that demonstrate the use of many of the module's features. These examples are in written in C and BASIC. Also included is an easy-to-use menu-driven diagnostics program, 5300DIAG, which is especially helpful when you are first checking out your module after installation and when calibrating the module (Chapter 6).

Before using the software included with your module, make a backup copy of the disk. You may make as many backups as you need.

C Programs

These programs are source code files so that you can easily develop your own custom software for your DM5300. In the C directory, 5300.H and 5300.INC contain all of the functions needed to implement the main C programs. H defines the addresses and INC contains the routines called by the main programs.

Analog-to-Digital:

READ	Demonstrates basic operation of A/D.
EXTTRIG	Similar to READ except that an external trigger is used.
INTRPT, MULTI	Single and multiple channel A/D conversions with interrupt

Digital I/O:

DIGITAL	Simple program the shows how to read and write the digital I/O lines.

Digital-to-Analog:

DAC	Shows how to use the DAC. Uses A/D channel 1 to monitor the output of the DAC.

Interrupts:

INTRPT	Shows the bare essentials required for using interrupts.

BASIC Programs

These programs are source code files so that you can you can easily develop your own custom software for your DM5300.

Analog-to-Digital:

READ	Demonstrates basic operation of A/D.
EXTTRIG	Similar to READ except that an external trigger is used.

Digital I/O:

DIGITAL	Simple program the shows how to read and write the digital I/O lines.

Digital-to-Analog:

DAC	Shows how to use the DAC. Uses A/D channel 1 to monitor the output of DAC.

CHAPTER 5 CALCULATING FREQUENCIES, VOLTAGES, AND BITS

This chapter contains tables, formulas, and examples to help you understand the principles of V/F conversion. Included are examples which show how to calculate the timer (binary and decimal) to gate the frequency counters and how to calculate the correction factor, tables showing the expected output frequencies for selected input voltages for each input range, and formulas for converting frequency to voltage and bits.

This chapter shows you how to calculate the contents of the 8254 timer which gates the 20-bit A/D conversion counter in both binary (bit-based resolution) and decimal (voltage-based resolution), how to calculate the true frequency of a conversion using the correction factor, expected frequency outputs for selected input voltages for each of the four analog input ranges, and how to convert frequency to voltage and bit values.

Calculating the Settings for the 8254 Timer

When performing voltage-to-frequency conversions, the resolution of your result is dependent on how long you look at the output of the converter. On the DM5300, a software selectable system clock drives the V/F converter. The converter divides this clock by 2 internally. Therefore, the output from the V/F converter will always be between 0 and the system clock ÷ 2 (full scale). Using the 20-bit conversion counter, you look at the output of the V/F converter for a specified period of time and count the number of transitions which occur in the output during that time frame. You can set your time period for binary or decimal, depending on whether you want to measure your resolution as a function of bits or voltage.

How long do you want to look at the current conversion before starting a new one? The window of time is set by two 16-bit timers on the 8254 PIT. These timers are cascaded to form a 32-bit timer which is programmed to open up the conversion counter so that you can obtain data at the accuracy level you need for your application. Below is a table showing resolution vs. conversion time at a 1 MHz system clock.

DM5300 A/D Conversion Resolution
(1 MHz System Clock)

RESOLUTION	CONVERSION TIME	FREQUENCY
10 bits	2.048 msec	488.28 Hz
11 bits	4.096 msec	244.14 Hz
12 bits	8.192 msec	122.07 Hz
13 bits	16.384 msec	61.04 Hz
14 bits	32.768 msec	30.52 Hz
15 bits	65.536 msec	15.26 Hz
16 bits	131.072 msec	7.63 Hz
17 bits	262.144 msec	3.81 Hz
18 bits	524.288 msec	1.90 Hz

Binary Calculations

To determine the binary value to be loaded into the timer for bit-based resolutions, you must first calculate what change in the output frequency of the V/F converter you must detect in order to achieve your desired resolution. Note that the input voltage range is not a factor in bit-based calculations. Then, you must divide the system clock which drives the 8254 (the same clock which drives the V/F converter) down to the value of this change in frequency. The result is the value you load into the timer. For example, let's set up the timer for 16-bit conversions.

1. Calculate the amount of change you must discern for 16 bits:

   2^{16} = 65,536, which means you must detect a 1 part change in 65,536 to have a resolution of 16 bits.
2. Next, convert this result into frequency (0.5 MHz = full scale with a 1 MHz system clock):

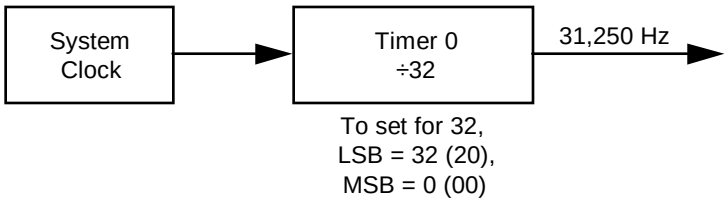
   500,000 Hz ÷ 65,536 = 7.629394 Hz
   This means that we must detect a change of 7.629394 Hz out of 0.5 MHz. Also note that this frequency, 7.629394 Hz, is the correction factor (see discussion in *Conversion Results and Correction Factor* section).

3. Next, we must divide the system clock which drives the 8254 by the change we must detect to determine the value we must program into the timer:

   1,000,000 ÷ 7.62394 = 1,000,000 ÷ (500,000 ÷ 65,536) = 2 x 65,536 = 131,072

   We need to divide the system clock by 131,072 to open the timer for the right amount of time, 131.072 milliseconds, to take 16-bit readings.

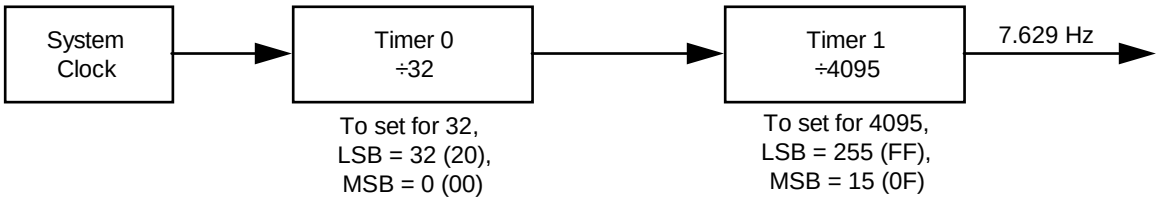
Counter 0 is programmed with the 16 least significant bits of the 32-bit timer word. All of our example programs use binary division and set counter 0 to 32. When counter 0 is 32, the 1 MHz clock is divided by 32 for a resulting 31,250 Hz clock into timer 1, as shown below:



Then, timer 1, which contains the 16 most significant bits of the 32-bit timer word, is programmed. The value to be programmed is determined by:

(131,072 ÷ 32) - 1 = 4095

The value we must program in timer 1 is 4095, as shown in the diagram below.



The values calculated using the formulas already presented will open the window of the counters for the right amount of time whenever you are doing conversions. Note that you always subtract 1 from the timer value in order to correct for the 8254's method of loading and counting. The table below shows the count which must be loaded into the timers for the listed bit-based resolutions for *Single Convert* and for *Continuous Convert* modes.

Resolution	Timer 0 LSB (Decimal/Hex)	Timer 0 MSB (Decimal/Hex)	Timer 1 LSB (Decimal/Hex)	Timer 1 MSB (Decimal/Hex)
12 bits	32 / 20	0 / 00	255 / FF	0 / 00
13 bits	32 / 20	0 / 00	255 / FF	1 / 01
14 bits	32 / 20	0 / 00	255 / FF	3 / 03
15 bits	32 / 20	0 / 00	255 / FF	7 / 07
16 bits	32 / 20	0 / 00	255 / FF	15 / 0F
17 bits	32 / 20	0 / 00	255 / FF	31 / 1F
18 bits	32 / 20	0 / 00	255 / FF	63 / 3F

Decimal Calculations

To determine the decimal value to be loaded into the timer for voltage-based resolutions, you must first calculate what change in the output frequency of the V/F converter you must detect in order to achieve your desired resolution. Unlike with the bit-based formulas, you must include the input voltage range in this calculation. Then, you must divide the system clock which drives the 8254 (the same clock which drives the V/F converter) down to the value of this change in frequency. The result is the value you load into the timer. For example, let's set up the timer for conversions with a resolution of 100 microvolts.

1. Calculate the amount of change you must discern for 100 microvolt resolution and an input range of 5 volts:

   5 V ÷ 100 µV = 50,000, which means you must detect a 1 part change in 50,000 to have a resolution of 100 microvolts.

2. Next, convert this result into frequency (0.5 MHz = full scale for a 1 MHz system clock):

   500,000 Hz ÷ 50,000 = 10 Hz

   This means that we must detect a change of 10 Hz out of 0.5 MHz. Also note that this frequency, 10 Hz, is the correction factor (see discussion in *Conversion Results and Correction Factor* section).

3. Next, we must divide the system clock which drives the 8254 by the change we must detect to determine the value we must program into the timer:

   1,000,000 ÷ 10 = 100,000

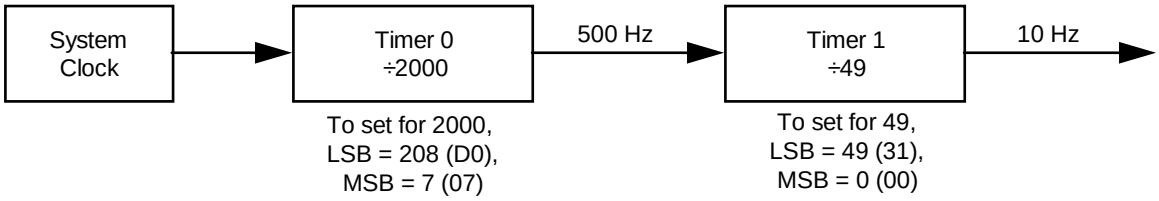
   We need to divide the 1 MHz clock by 100,000 to open the timer for the right amount of time, 100 milliseconds, to take 100 microvolt resolution readings.

Counter 0 is programmed with the 16 least significant bits of the 32-bit timer word. When counter 0 is 2000, the 1 MHz clock is divided by 2000 for a resulting 0.5 kHz clock into timer 1.

Then, timer 1, which contains the 16 most significant bits of the 32-bit timer word, is programmed. The value to be programmed is determined by:

(100,000 ÷ 2000) - 1 = 49

The value we must program in timer 1 is 49, as shown in the diagram below.



Like in binary calculations, the values calculated using the formulas already presented will open the window of the counters for the right amount of time whenever you are doing conversions. Note that you always subtract 1 from the timer value in order to correct for the 8254's method of loading and counting. The two tables on the following page show the count which must be loaded into the timers for input ranges of 5 volts or 10 volts for the listed voltage-based resolutions.

For 5-volt Input Ranges:				
Resolution	**Timer 0 LSB (Decimal/Hex)**	**Timer 0 MSB (Decimal/Hex)**	**Timer 1 LSB (Decimal/Hex)**	**Timer 1 MSB (Decimal/Hex)**
10 mV	250 / FA	0 / 00	3 / 03	0 / 00
1 mV	208 / D0	7 / 07	4 / 04	0 / 00
100 µV	208 / D0	7 / 07	49 / 31	0 / 00
10 µV	208 / D0	7 / 07	243 / F3	1 / 01

For 10-volt Input Ranges:				
Resolution	**Timer 0 LSB (Decimal/Hex)**	**Timer 0 MSB (Decimal/Hex)**	**Timer 1 LSB (Decimal/Hex)**	**Timer 1 MSB (Decimal/Hex)**
10 mV	244 / FA	1 / 01	3 / 03	0 / 00
1 mV	208 / D0	7 / 07	9 / 09	0 / 00
100 µV	208 / D0	7 / 07	99 / 63	0 / 00
10 µV	208 / D0	7 / 07	231 / E7	3 / 03

Conversion Results and Correction Factor

For each conversion, when you count the output of the V/F converter, you increment a 20-bit counter by one for each pulse counted. For example, let's program the timer to open the gate for the counter for a period of 131.072 milliseconds. We read the data from the counter in three 8-bit words, ADLB (low byte), ADMB (middle byte), and ADHB (high byte). To find the true frequency represented by the count, you calculate:

True Frequency = [(ADLB + (ADMB x 256) + (ADHB x 65536)] x CF

where CF is the correction factor.

After performing the multiplication by the bit weight for each of the three bytes read, you must then multiply the result by CF, the correction factor, in order to find the true frequency of the signal you measured. The correction factor is the inverse of the amount of time you had the counter gated open for counting:

CF = 1/Gate Time

For example, if you count a 10 Hz signal for 1 second, your count would be 10. This is multiplied by a correction factor of 1, which is the same as 1 ÷ 1 second. If you count the same 10 Hz signal for 0.5 seconds, your count would be 5. This is multiplied by a correction factor of 2 (1 ÷ 0.5 seconds) which again gives you the true frequency of 10 Hz. Counting 10 Hz for 2 seconds gives you a count of 20 which is then multiplied by a correction factor of 0.5 (1 ÷ 2 seconds) for a result of 10 Hz. In contrast, a more complex example is counting for 131.072 milliseconds (our 16-bit resolution example given above). The correction factor is 1 ÷ 0.131072, or 7.629.

The upper four bits of the high byte (ADHB) contain the measurement overflow, counter overflow, and conversion done flags. These flags must be masked out when you calculate the frequency or voltage value.

Input Voltages and Output Frequencies

The analog inputs can be set up for four ranges: 0 to +5, 0 to +10, -2.5 to +2.5, and -5 to +5 volts. The following tables show the expected output frequencies for selected input voltages in each range for a 1 MHz system clock.

For 0 to +5 V range: (Frequency = 100,000 x Input Voltage)	
Input Voltage	**Output Frequency**
5V	500,000 Hz
3.75V	375,000 Hz
2.5V	250,000 Hz
1.25V	125,000 Hz
0V	0 Hz

For 0 to +10 V range: (Frequency = 50,000 x Input Voltage)	
Input Voltage	**Output Frequency**
10V	500,000 Hz
7.5V	375,000 Hz
5V	250,000 Hz
2.5V	125,000 Hz
0V	0 Hz

For -2.5 to +2.5 V range: (Frequency = 100,000 x (Input Voltage + 2.5))	
Input Voltage	**Output Frequency**
+2.5V	500,000 Hz
+1.25V	375,000 Hz
0V	250,000 Hz
-1.25V	125,000 Hz
-2.5V	0 Hz

For -5 to +5 V range: (Frequency = 50,000 x (Input Voltage + 5))	
Input Voltage	**Output Frequency**
+5V	500,000 Hz
+2.5V	375,000 Hz
0V	250,000 Hz
-2.5V	125,000 Hz
-5V	0 Hz

Input Voltage Calculations

The general formula for calculating the input voltage when the frequency and voltage range are known is:

Input Voltage = (Frequency/(system clock ÷ 2/Voltage Range) - Offset

The offset is 0 for unipolar voltage ranges and one-half the range for bipolar voltage ranges.

For 0 to +5 volts:

Input Voltage = (Frequency/100,000) - 0

For 0 to +10 volts:

Input Voltage = (Frequency/50,000) - 0

For -2.5 to +2.5 volts:

Input Voltage = (Frequency/100,000) - 2.5

For -5 to +5 volts:

Input Voltage = (Frequency/50,000) - 5

Bit Calculations

The general formula for calculating the bit value when the frequency and resolution are known is:

Bit Value = (Frequency/(system clock ÷ $2/2^N$)) - Offset

where N = the number of bits of the desired resolution,
and the offset is 0 for unipolar operation and 0.5 x 2^N for bipolar operation.

For example, to calculate the bit value for a 12-bit resolution:

Unipolar: Bit Value = (Frequency/(system clock ÷ 2/4096)) - 0
= Frequency/122.07

Bipolar: Bit Value = (Frequency/(system clock ÷ 2/4096)) - 2048
= (Frequency/122.07) - 2048

For example, to calculate the bit value for a 16-bit resolution:

Unipolar: Bit Value = (Frequency/(system clock ÷ 2/65,536)) - 0
= Frequency/7.629

Bipolar: Bit Value = (Frequency/(system clock ÷ 2/65,536)) - 32,768
= (Frequency/7.629) - 32,768

CHAPTER 6 CALIBRATION

This chapter tells you how to calibrate the DM5300 using the 5300DIAG diagnostics program included in the example software package and the four trimpots on the board. These trimpots calibrate the V/F converter gain and offset and the D/A circuitry. Calibration is necessary whenever you change the analog input voltage range and/or polarity.

This chapter tells you how to calibrate the V/F converter gain and offset and the D/A converter X2 multiplier. The offset and full-scale performance of the board's V/F converter is factory-calibrated for ±2.5 volts. If you change the range and/or polarity, you must recalibrate your module. Any time you suspect inaccurate readings, you can check the accuracy of your conversions using the procedure below, and make adjustments as necessary.

Calibration is done with the module installed in your system. You can access the trimpots at the edge of the module. Power up the system and let the module circuitry stabilize for 15 minutes before you start calibrating.

Required Equipment

The following equipment is required for calibration:

- 5300DIAG Diagnostics Program (included with example software)
- Precision Voltage Source: ±10 volts
- Digital Voltmeter: 5-1/2 digits
- Small Screwdriver (for trimpot adjustment)

Figure 6-1 shows the module layout. The four trimpots used for calibration, TR1, TR2, TR4, and TR5, are located in the upper center area of the board.

V/F Calibration

Two adjustments are made to calibrate the V/F converter. One is the offset adjustment, and the other is the full scale, or gain, adjustment. Trimpot TR2 is used to make the offset adjustment, and trimpot TR1 is used for gain adjustment.

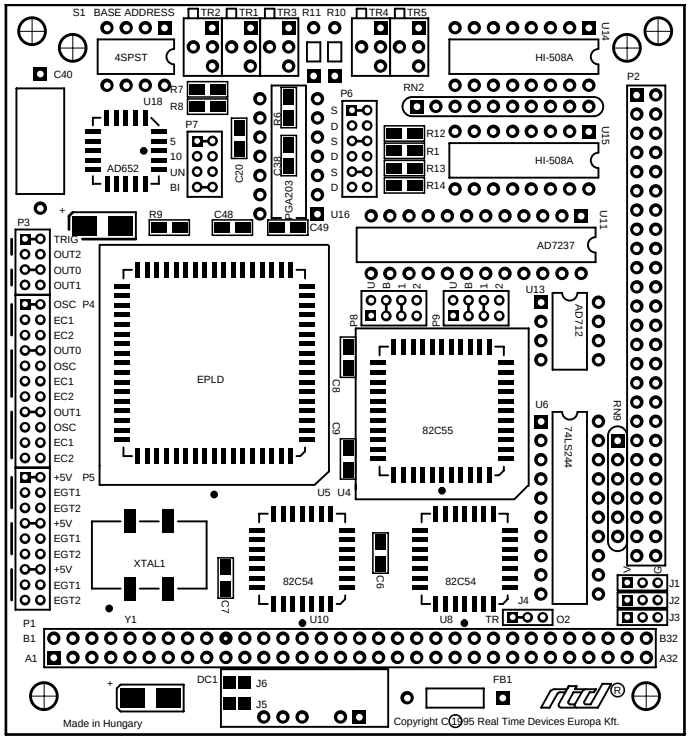


Fig. 6-1 — Module Layout

Connect your voltage source to channel 1 on the DM5300. Use Table 6-1 to set the voltage for your input range and desired adjustment (offset or gain). Then run the 5300DIAG program, adjusting the appropriate trimpot until the input voltage and V/F converter output reading match.

Table 6-1 — A/D Offset and Gain Adjustments		
Input Voltage	**TR1, Gain**	**TR2, Offset**
0 to +5 volt input range:		
.0001 V	—	.0001 V
+4.75 V	+4.75V	—
0 to +10 volt input range:		
.0001 V	—	.0001 V
+9.75 V	+9.75 V	—
-2.5 to +2.5 volt input range:		
0 V	—	0 V
+2.25 V	+2.25 V	—
-5 to +5 volt input range:		
0 V	—	0 V
+4.75 V	+4.75 V	—

D/A Calibration

The D/A converter requires no calibration for the X1 ranges (0 to +5 and ±5 volts). The following paragraph describes the calibration procedure for the X2 multiplier ranges.

To calibrate for X2 (0 to +10 or ±10 volts), set the DAC output voltage range to 0 to +10 volts (jumpers on X2 and U on P6, AOUT1, or P7, AOUT2). Then, program the corresponding D/A converter (DAC1 or DAC2) with the digital value 2048. The ideal DAC output for 2048 at X2 (0 to +10 volt range) is 5.0000 volts. Adjust TR4 for AOUT1 and TR5 for AOUT2 until 5.0000 volts is read at the output. Table 6-2 lists the ideal output voltages per bit weight for unipolar ranges and Table 6-3 lists the ideal output voltages for bipolar ranges.

Table 6-2 — D/A Converter Unipolar Calibration Table		
	Ideal Output Voltage (in millivolts)	
D/A Bit Weight	0 to +5 V	0 to +10 V
4095 (Max. Output)	4998.8	9997.6
2048	2500.0	5000.0
1024	1250.0	2500.0
512	625.0	1250.0
256	312.50	625.00
128	156.250	312.50
64	78.125	156.250
32	39.063	78.125
16	19.5313	39.063
8	9.7656	19.5313
4	4.8828	9.7656
2	2.4414	4.8828
1	1.2207	2.4414
0	0.0000	0.0000

Table 6-3 — D/A Converter Bipolar Calibration Table		
	Ideal Output Voltage (in millivolts)	
D/A Bit Weight	±5 V	±10 V
4095 (Max. Output)	+4997.6	+9995.1
2048	0.0	0.0
1024	-2500.0	-5000.0
512	-3750.0	-7500.0
256	-4375.0	-8750.0
128	-4687.5	-9375.0
64	-4843.8	-9687.5
32	-4921.9	-9843.8
16	-4960.9	-9921.9
8	-4980.5	-9960.9
4	-4990.2	-9980.5
2	-4995.1	-9990.2
1	-4997.6	-9995.1
0	-5000.0	-10000.0

APPENDIX A DM5300 SPECIFICATIONS

DM5300 Characteristics Typical @ 25° C

Interface

Switch-selectable base address, I/O mapped
Software-selectable interrupt

Analog Input

8 differential, 16 single-ended
Input impedance, each channel ..... >10 megohms
Input ranges ..... 0 to +5, 0 to +10, ±2.5, or ±5 volts
Overvoltage protection ..... ±35 Vdc
Gains, software selectable ..... 1, 2, 4 & 8 plus Gm gain multiplier
Gain error ..... 0.05%, typ; 0.25%, max
Common mode input voltage ..... ±10 volts, max
Settling time (gain = 1) ..... 10 µsec, max

V/F Converter AD652

Type ..... Synchronous
Resolution ..... to 18 bits (19 µV, 5-volt range)
Linearity error ..... 0.005%, max
Conversion speed ..... See table below

Digital I/O ..... CMOS 82C55

Number of lines 16
Logic compatibility ..... TTL/CMOS
(Configurable with optional I/O pull-up/pull-down resistors)
High-level output voltage ..... 4.2V, min
Low-level output voltage ..... 0.45V, max
High-level input voltage ..... 2.2V, min; 5.5V, max
Low-level input voltage ..... -0.3V, min; 0.8V, max
Input load current ..... ±10 µA
Input capacitance,
C(IN)@F=1MHz ..... 10 pF
Output capacitance,
C(OUT)<@F=1MHz ..... 20 pF

D/A Converter AD7237

Analog outputs ..... 2 channels
Resolution ..... 12 bits
Output ranges ..... 0 to +5, ±5, 0 to +10, or ±10 volts
Guaranteed linearity across output ranges (DM300)
..... 0 to +5, ±5, 0 to +9.2, and ±9.2 volts
Guaranteed linearity across output ranges (DM5300)
..... 0 to +5, ±5, 0 to +10, and ±10 volts
Relative accuracy ..... ±1 LSB, max
Full-scale accuracy ..... ±5 LSB, max
Non-linearity ..... ±1 LSB, max
Settling time ..... 10 µsec, max
Output current ..... 5 ma, typ

Timer/Counters ..... CMOS 82C54

Three 16-bit down counters (2 cascaded, 1 independent)
6 programmable operating modes
Counter input source ..... External clock (8 MHz, max) or
on-board 2 MHz clock
Counter outputs ..... Available externally
Counter gate source ..... External gate or always enabled

Miscellaneous Inputs/Outputs (PC bus-sourced)

+5 volts, ±12 volts, ground

Current Requirements

DM5300 ..... 440 mA @ +5 volts
DM300 ..... ==190 ma @ +5 volts, 42 ma @ +12 volts, 32 ma @ -12 volts

Connector

50-pin right angle header

Environmental

Operating temperature ..... 0 to +70°C
Storage temperature ..... -40 to +85°C
Humidity ..... 0 to 90% non-condensing

Size

3.55"L x 3.775"W x 0.6"H (90mm x 96mm x 16mm)

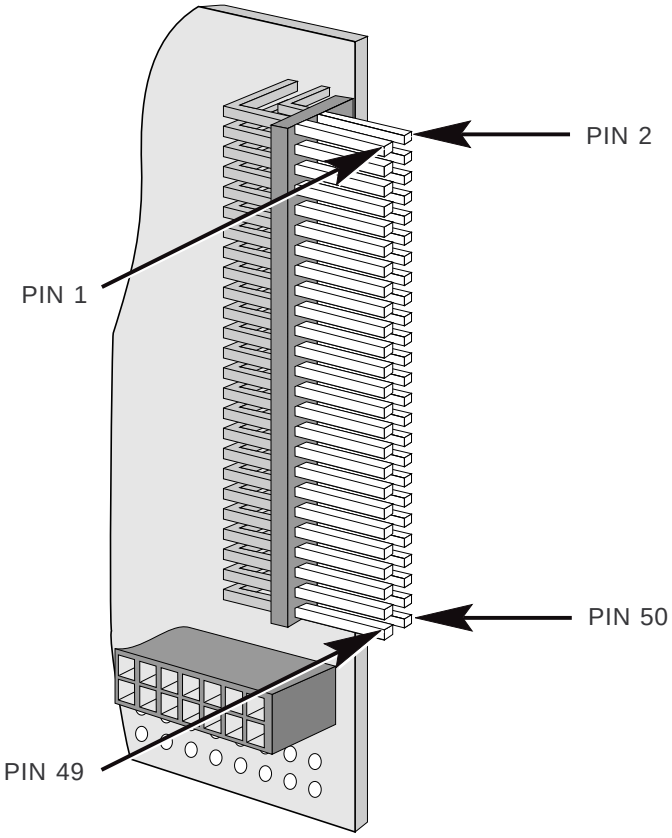
DM5300 A/D Conversion Resolution
(1 MHz System Clock)

RESOLUTION	CONVERSION TIME	FREQUENCY
10 bits	2.048 msec	488.28 Hz
11 bits	4.096 msec	244.14 Hz
12 bits	8.192 msec	122.07 Hz
13 bits	16.384 msec	61.04 Hz
14 bits	32.768 msec	30.52 Hz
15 bits	65.536 msec	15.26 Hz
16 bits	131.072 msec	7.63 Hz
17 bits	262.144 msec	3.81 Hz
18 bits	524.288 msec	1.90 Hz

APPENDIX B P2 CONNECTOR PIN ASSIGNMENTS

P2 Connector:

DIFF.	S.E.			DIFF.	S.E.
AIN1+	AIN1	1	2	AIN1-	AIN9
AIN2+	AIN2	3	4	AIN2-	AIN10
AIN3+	AIN3	5	6	AIN3-	AIN11
AIN4+	AIN4	7	8	AIN4-	AIN12
AIN4+	AIN5	9	10	AIN5-	AIN13
AIN6+	AIN6	11	12	AIN6-	AIN14
AIN7+	AIN7	13	14	AIN7-	AIN15
AIN8+	AIN8	15	16	AIN8-	AIN16
	AOUT 1	17	18	ANALOG GND	
	AOUT 2	19	20	ANALOG GND	
	ANALOG GND	21	22	ANALOG GND	
	PA7	23	24	PC7	
	PA6	25	26	PC6	
	PA5	27	28	PC5	
	PA4	29	30	PC4	
	PA3	31	32	PC3	
	PA2	33	34	PC2	
	PA1	35	36	PC1	
	PA0	37	38	PC0	
	TRIGGER IN	39	40	DIGITAL GND	
	EXT CLK1	41	42	EXT GATE1	
	TRIGGER OUT / OUT2	43	44	OUT0 / OUT1	
	EXT CLK2	45	46	EXT GATE2	
	+12 VOLTS	47	48	+5 VOLTS	
	-12 VOLTS	49	50	DIGITAL GND	



Mating Connector Part Numbers	
Manufacturer	**Part Number**
AMP	1-746094-0
3M	3425-7650

APPENDIX C COMPONENT DATA SHEETS

Intel 82C54 Programmable Interval Timer
Data Sheet Reprint

8255 Programmable Peripheral Interface
Data Sheet Reprint

APPENDIX D WARRANTY AND RETURN POLICY

Return Policy

If you wish to return a product to the factory for service, please follow this procedure:

Read the Limited Warranty to familiarize yourself with our warranty policy.

Contact the factory for a Return Merchandise Authorization (RMA) number.

Please have the following available:

- Complete board name
- Board serial number
- A detailed description of the board's behavior

List the name of a contact person, familiar with technical details of the problem or situation, **along with their phone and fax numbers, address, and e-mail address** (if available).

List your shipping address!!

Indicate the shipping method you would like used to return the product to you.
We will not ship by next-day service without your pre-approval.

Carefully package the product, using proper anti-static packaging.

Write the RMA number in large (1") letters on the outside of the package.

Return the package to:

RTD Embedded Technologies, Inc.
103 Innovation Blvd.
State College PA 16803-0906
USA

LIMITED WARRANTY

RTD Embedded Technologies, Inc. warrants the hardware and software products it manufactures and produces to be free from defects in materials and workmanship for one year following the date of shipment from RTD Embedded Technologies, INC. This warranty is limited to the original purchaser of product and is not transferable.

During the one year warranty period, RTD Embedded Technologies will repair or replace, at its option, any defective products or parts at no additional charge, provided that the product is returned, shipping prepaid, to RTD Embedded Technologies. All replaced parts and products become the property of RTD Embedded Technologies. Before returning any product for repair, customers are required to contact the factory for an RMA number.

THIS LIMITED WARRANTY DOES NOT EXTEND TO ANY PRODUCTS WHICH HAVE BEEN DAMAGED AS A RESULT OF ACCIDENT, MISUSE, ABUSE (such as: use of incorrect input voltages, improper or insufficient ventilation, failure to follow the operating instructions that are provided by RTD Embedded Technologies, “acts of God” or other contingencies beyond the control of RTD Embedded Technologies), OR AS A RESULT OF SERVICE OR MODIFICATION BY ANYONE OTHER THAN RTD Embedded Technologies. EXCEPT AS EXPRESSLY SET FORTH ABOVE, NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, AND RTD Embedded Technologies EXPRESSLY DISCLAIMS ALL WARRANTIES NOT STATED HEREIN. ALL IMPLIED WARRANTIES, INCLUDING IMPLIED WARRANTIES FOR MECHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE LIMITED TO THE DURATION OF THIS WARRANTY. IN THE EVENT THE PRODUCT IS NOT FREE FROM DEFECTS AS WARRANTED ABOVE, THE PURCHASER’S SOLE REMEDY SHALL BE REPAIR OR REPLACEMENT AS PROVIDED ABOVE. UNDER NO CIRCUMSTANCES WILL RTD Embedded Technologies BE LIABLE TO THE PURCHASER OR ANY USER FOR ANY DAMAGES, INCLUDING ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES, EXPENSES, LOST PROFITS, LOST SAVINGS, OR OTHER DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE PRODUCT.

SOME STATES DO NOT ALLOW THE EXCLUSION OR LIMITATION OF INCIDENTAL OR CONSEQUENTIAL DAMAGES FOR CONSUMER PRODUCTS, AND SOME STATES DO NOT ALLOW LIMITATIONS ON HOW LONG AN IMPLIED WARRANTY LASTS, SO THE ABOVE LIMITATIONS OR EXCLUSIONS MAY NOT APPLY TO YOU.

THIS WARRANTY GIVES YOU SPECIFIC LEGAL RIGHTS, AND YOU MAY ALSO HAVE OTHER RIGHTS WHICH VARY FROM STATE TO STATE.

RTD Embedded Technologies, Inc.
103 Innovation Blvd.
State College PA 16803-0906
USA
Our website: www.rtd.com

DM5300 Board User-Selected Settings	
Base I/O Address:	
(hex)	(decimal)